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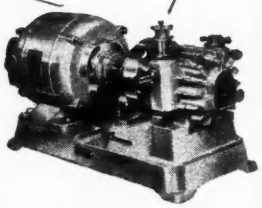

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DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

February, 1948 Vol. IX. No. 2

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The Progress of Science

The Motivation of Scientific Work

THE question, "Why do scientists work?", is a perennial source of argument—do they work for personal intellectual satisfaction, for money or prestige, for the value of their results to society, or what? The argument is usually confused by a number of tacit assumptions. It is often assumed, for instance, that the urges which drive scientists are necessarily the same in all ages and places; or again that the scientists' avowed reasons are the same as those that would be discovered by the scrutiny of some ideal super-psychologist. But whatever the degree of truth in these and other assumptions, it is gratifying to have at last some concrete information on at least one particular aspect of the problem: the conscious opinions of American scientists of 1947 as to why they pursue their profession. This comes from an opinion survey reported in *Administration for Research*.*

One actual question asked was, "What special satisfactions do you think a person can get out of a career in science, in contrast to other occupations?" The subjects were allowed to name more than one satisfaction, so that the percentages we quote are not simply additive. The satisfactions that can be classed as 'intellectual and temperamental' easily head the list. 'Learning how things work' was given by 31% of the sample; 'variety, discovery, challenge' by 22%, and 'creative satisfaction' by 9%, making a total of 62%. 'Social value of the work' comes next, but only moderately high, with 28%. And the only other figure over 10% was 15% for the ambiguous answer that scientific work gives 'tangible results'.

The figures are analysed in the report for the opinions of government, industrial and university scientists. On the whole there are no very great differences between these groups. But it is remarkable that university scientists give considerably less prominence to 'intellectual and temperamental satisfactions'—57% against 68% for government and 65% for industrial scientists. Again, only 22% of the university men mentioned 'social value', against 36% of the government and 31% of the industrial workers. The university scientists found greater satisfaction in 'human contacts' and the environment of scientific work than their fellows in industrial and government services: 11% of university scientists gave this as one of the special satisfactions of scientific work as against 2% of government scientists and 1% of industrial scientists.

On the other hand, when a more specifically social question was put, "How much concern do you feel about the contribution your own work in science is likely to make to the welfare of people in general?", a far higher degree of social conscience emerged. There were answers of 'deep concern' from 48%, 'moderate concern' from 35%, 'only slight concern' from 16% and 'don't know' from 1%. Comparison of these answers with those given to the more personal question about satisfactions suggests that a majority of American scientists would agree with the attitude expressed by A. K. Solomon in the preface to his book, *Why Smash Atoms?*—"I am a scientist because it is fun, because I have the opportunity of doing the things I like to do. If I felt that what I did was of no importance and that smashing atoms was my personal retreat into a less than ivory tower, I should soon cease to find it fun. Only as long as I am satisfied that the work is necessary can I enjoy myself putting in the long hours and hard work that science demands."

The more wordly satisfactions of 'prestige, recognition' (3%) and 'economic rewards, security' (1%) hardly count at all in the opinion of American scientists. At this point one might be inclined to suspect that a sense of the 'done thing' would bias these figures downwards. But on the whole the survey presents a considerable amount of internal evidence that the answers are honest. If there are deceptions, they are unconscious self-deceptions. And in this case the honesty of the answer is backed up by the fact that 78% believe the rewards (financial, prestige, etc.) that accrue in American scientists are less

* This is the third volume of *Science and Public Policy*, which is the title given to the report of the U.S. President's Scientific Research Board published by the U.S. Government Printing Office and obtainable through H.M. Stationery Office. The other volumes deal with the following aspects of the organisation of American science. Vol. I sketches the country's present position in research and development and outlines a programme for expanding the scientific effort. Vol. II reviews the federal government's scientific organisation agency by agency; Vol. IV deals with man-power for research, and Vol. V with medical research.

FIG. 1.—Comfort and efficiency are combined in the scientifically designed seats used by the Services. This photograph shows Admiral R. A. Spruance of the U.S. Navy testing a seat used in the British Navy by aircraft 'spotters' and perfected for the R.N. Research Committee by research workers of the Department of Human Anatomy of Oxford University. The Oxford scientists in the photograph are (*left to right*): Prof. W. E. Le Gros Clark, Dr. H. Darcus, Dr. J. Walley and Dr. G. Weddell.

than they should be (19% said 'about right', and 1% 'greater'). Presumably anybody believing the financial and prestige rewards were too small would not choose science as a career unless other incentives were more important to him. British scientists will sympathise with their American colleagues' feeling that their rewards are too low; but they would probably be very glad to have the salary with which their American counterparts are discontented—only 19% of those who answered the questionnaire had incomes of less than £750 a year; 43% between £750 and £1250; 30% between £1250 and £2000; and the substantial proportion of 8% over £2000 (reckoning at four dollars to the pound).

Cool Clothes and Comfortable Seats

To most people in this country clothes mean something to keep us warm by preventing the body-warmth from escaping. In the tropics, however, the problem is to find clothes which will allow this warmth to escape as quickly as possible to the environment. This heat loss varies with the kind of fabric. Before the war practically no scientific assessment of textiles according to their use for tropical clothing had been made. But the war brought many clothing problems to be examined by the Climatic Unit of Britain's Medical Research Council, an account of whose work is published in the latest number of *British Medical Bulletin* (1947, Vol. 5, No. 1).

The evaluation of the physiological role of clothing in any particular situation does not in principle involve any very difficult physical problems, says Dr. J. S. Weiner, one of the many investigators of war-time problems in the field of personnel research who contribute to this special number of the *British Medical Bulletin*. In practice, however, and particularly when considering tropical climates, a very elaborate procedure is necessary for a complete analysis of the heat exchange between an active clothed man and the environment. Studies had to be carried out on the thermal insulation of the clothing, its resistance to moisture diffusion and its surface-coefficients of loss of heat and water-vapour.

Fabrics were also tested for mosquito-proofness. For these tests a convenient method was developed in which a 2-in. square of the fabric was stained with the dye called fuchsin, placed in front of a light source and photographed. Of 57 fabrics tested, twenty showed no light penetration and were regarded as mosquito-proof; nine showed a few fine pin-points of light, indicating they were penetrable with difficulty; and twenty-eight showed light areas which meant that these fabrics would be penetrable by mosquitoes. The bush-shirt fabric of the Army's tropical uniform was found to be of open construction and easily penetrable by mosquitoes. Only seven fabrics were found which from their physical characters and availability could be considered as possible substitutes for the army fabric. With only one exception these fabrics were of lighter and finer construction than the cellular bush-shirt. The fabric finally recommended by the Medical Research Unit for a hot, wet climate was a twill, 'utility' gabardine 3170, a non-water-repellant fabric.

Another series of experiments which may have important peace-time applications were those carried out to find the best design of seats for the sailors operating naval gun-sights and other instruments. Prolonged standing at work is probably one of the commonest causes of avoidable discomfort and fatigue, but until recently the provision of seats was considered unnecessary and even undesirable. Seats had been thought to encourage laziness, and thus, in the armed forces especially, it has been traditional for the operator to stand at his work. Nowadays, however, employers (and the Navy) have been persuaded that seats not only afford a valuable method of combating fatigue but also enable work to be performed with greater accuracy.

The seats, though, must be designed on certain anatomical and physiological principles if the maximum efficiency is to be obtained. A seat must support the body in a normally comfortable position and be spaced so that the operator is in the optimum relation to his work. To arrive at the best design close co-operation is necessary between the anatomist and the seat engineer, a factor which has been neglected in the past. Experiments were carried out to find the best design of seats for use with naval optical sights, but from these certain general principles can be formulated which can equally well be applied to civilian problems.

The ideal seat for use with naval weapons had to accommodate 90% of individuals of different body dimensions in the most efficient position, permit the maximum

degree of body stabilisation, allow the operator to maintain a sitting position for periods up to four hours without undue fatigue, and allow for an alert and relaxed position. It had to combine lightness with mechanical efficiency and withstand very severe usage. It was found that the seat cushion had to be wide enough to accommodate most ratings, with a depth to afford light support for the thighs almost to the hollow of the knees. It had to be resilient but with little lateral sway, and the resilience had to be of such degree that the body weight was distributed over as large an area as possible. If the seat cushion is too soft the excessive transfer of pressure to adjacent parts may cause serious discomfort. A foot-rest had to be placed so that at the ankle the foot is maintained at right-angles to the leg. A back-rest to afford comfortable resistance against which the body could be pressed to keep it steady was provided. The experimenters thought that, although many of the principles of seating discovered in their investigations may be applied to the design of seats for industrial purposes, it is important to realise that the final design of a seat in any particular industrial situation must be considered as an individual problem.

FIG. 2.—Improved comfort can result from the application of anatomical knowledge to ordinary seating problems. The designing of the seats in this railway coach was based on human measurements made by the American anthropologist, Dr. Earnest Hooton of Harvard University. (*General Motors photograph.*)

Synthetic Vitamin A

NEW vitamins or variants of familiar ones are still being discovered at frequent intervals, and the 'fat-soluble A' and 'water-soluble B' of 1915 have now given place to a series of between twenty and thirty quite well-defined vitamins, together with a large number of somewhat indefinite entities, some of which may graduate into respectable members of the vitamin family as their investigation proceeds. Among these candidates at present, for example, are an 'anti-stiffness factor for guinea-pigs' and a 'weight restoration factor for pigeons'. The stories of most vitamins are similar in outline, and standard chapter headings might well be Postulation, Isolation, Elucidation, Fabrication and—frequently—Exploitation. The story is still incomplete for many of the vitamins, even for some of the oldest and best known ones, and when a new chapter can be added to the history of such a worthy foundation member as vitamin A, a stir is bound to be caused in scientific circles for it will indicate that a solution to some baffling problem has at last been achieved. The recent synthesis of vitamin A is a good example of this.

The 'postulation phase' of vitamin A occurred over a number of years as the idea of the existence of vitamins was debated and finally accepted and the existence shown of at least two different factors, termed 'fat-soluble A' and 'water-soluble B'. Both these have turned out to be complex mixtures, and are continually being split up into more and more individual components, and the one in 'fat-soluble A' which will cure the deficiency disease of xerophthalmia (which may lead to total blindness), has become known as vitamin A. The discovery that fish-liver oils were rich sources of the vitamin opened the way to its isolation in 1931 by Paul Karrer in Switzerland, and although he did not obtain it pure, he was able to determine its structure from the highly concentrated preparations that he made. He was aided in this work on the structure by his previous work on the carotenes, which pigments occur in plants (e.g. the carrot). These can be converted by the animal body into vitamin A, which occurs as such only in animal tissues and is not found in plants. A close relationship in structure was expected and established. The blue print of the vitamin molecule thus became known and the stage set for the synthesis in the laboratory. The aim of this was twofold. Synthesis gives the final confirmation of the proposed structure, and it may also open up the possibilities of commercial production. Teams of workers in several countries, especially in Switzerland, England, America and Germany immediately tackled the problem, and while a great deal of useful knowledge was discovered in the course of this work and published, the vitamin itself proved very elusive. A number of claims to have succeeded in making it were announced, among them that of Kuhn and Morris who claimed a preparation with a vitamin A activity corresponding to about 7·5% vitamin A content as judged by physical and biological tests. Although details of these experiments were published, other teams of workers in Switzerland, England, Russia and most recently of all, in Germany itself have been quite unsuccessful in attempts to reproduce this work and obtain active material. The real proof of a successful synthesis of a natural product is the preparation of a 100% pure compound identical in all physical, chemical and biological properties with the pure natural material, and Kuhn and Morris only produced an impure preparation. This, and the inability of other workers to conform the synthesis, has caused very considerable doubts to be cast on the validity of the claim. During the last few years, however, several teams working independently have achieved the desired goal by different routes. In Holland, van Dorp

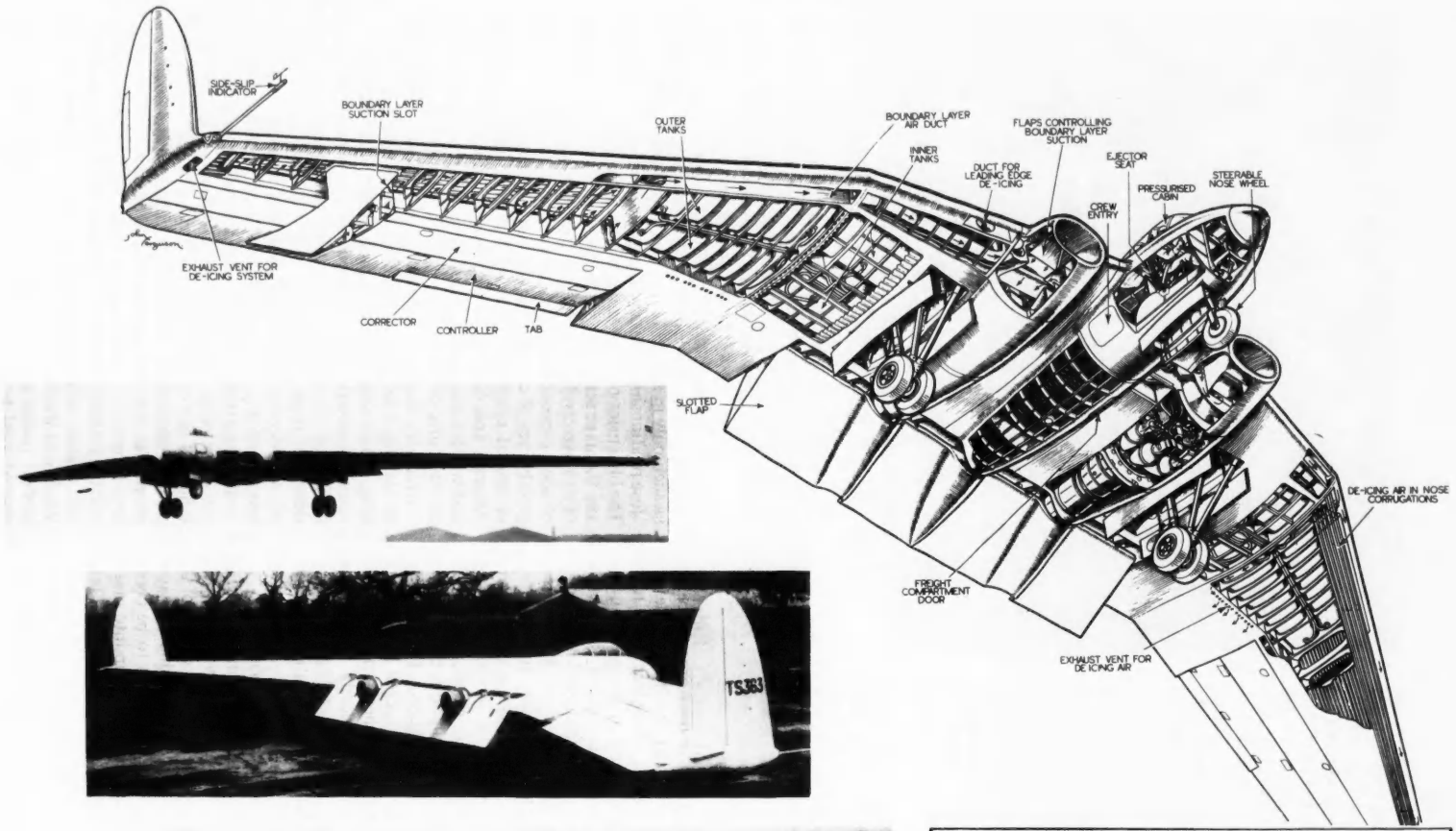

FIG. 3.—A.F. 52, a full-scale plane built for research purposes, made its first public appearance in December, when it was demonstrated in flight over Bitteswell airfield near Rugby. Details of its construction, involving many revolutionary features, are shown in the diagram, which is reproduced by courtesy of the editor of *Flight*. The photographs were taken during December's demonstration flight. The plane, which weighs 33,000 pounds, is powered by two Rolls-Royce 'Nene' engines. Maximum speed is about 500 m.p.h., and its normal range is 1500 miles at 36,000 feet, which can be extended to 2130 miles with the fitting of overload tanks. The rate of climb at ground level is 4800 feet per minute.

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and Arens working in the Organon Laboratory at Oss made a substance very closely related to vitamin A in 1944, and by a modification of the process obtained the vitamin itself in June 1947. Milas at the Massachusetts Institute of Technology reported in 1946 that he had obtained biologically active vitamin-A substances, which were 50–100 times as active as ordinary cod-liver oil, one of the chief sources of the vitamin. Most definite of all perhaps is the synthesis developed by a team in the laboratories of Distillation Products of New York, which has yielded pure crystalline vitamin A, and a sample of this synthetic product has been exhibited at a meeting of the American Chemical Society last autumn.

A few days before the American workers gave their paper on synthetic vitamin A, a group of chemists working in the laboratories of Hoffmann-La-Roche in Basle reported to a meeting of the Swiss Chemical Society that they had succeeded in synthesising crystalline vitamin A—a good example of how important scientific discoveries are often made almost simultaneously in different countries.

This synthetic material is totally free from the fishy odour which has made many natural concentrates unsuitable for use in certain foods and medical preparations. Rapid progress is being made and pilot plant samples will be available shortly for experimental purposes, and commercial production, it is hoped, will follow as soon as possible.

Vitamin A affects vision and growth, and a deficiency of it is accompanied by an increased liability to infection, so that the substance has been described as the anti-infective vitamin. Manufacture on a large scale would be most opportune at present, when the commercial sources of fish-liver oils are restricted in supply and when, owing to the world food shortage, very large numbers of people will be unable to include in their diets an adequate amount of fresh fruit and vegetables, which if plentiful could supply adequate amounts of the substitutes for the vitamin, the carotenes.

A British 'Flying Wing'

THE successful flight of the A. W. 52 research aircraft at the end of 1947 was a notable achievement because many aerodynamic innovations are included in the design of this 'flying wing' (Fig. 3, opposite). Every effort has been made to reduce the drag of the aeroplane to the lowest possible value, with consequent benefit to its operating performance.

With any aircraft the parasitic drag arises from two sources, namely the *skin friction*, i.e., the shearing effects between the body surface and the air flow, and the *form drag*, caused by the disturbances and eddies created by the passage of the aircraft. By reducing the fuselage until it is no more than a bulge to accommodate the pilot and by removing the tail, the surface area, and hence the drag due to skin friction, is reduced; the 'cleaner' shape also helps to reduce the form drag, since the air flows more smoothly past the small streamlined bulge.

The characteristic form of the wing of a tailless aircraft is a very oblique V, with the leading edges of the wing swept back. In this way the forces are distributed over the wing so that it is stable and controllable; a normal aeroplane wing is by itself unstable and uncontrollable, which is why a tail must be added to it some distance

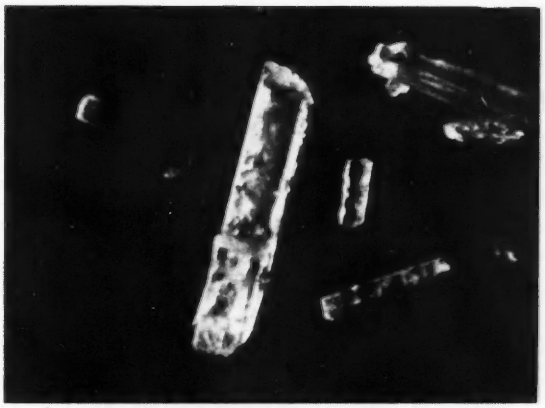


FIG. 4.—Synthetic vitamin A crystals (from the paper by Isler, Huber, Ronco and Kofler, *Helvetica Chimica Acta*, 1947, Vol. 30, p. 1911).

behind. By a fortunate coincidence this sweeping back of the wing helps the aircraft when it is travelling at very high speeds, as it has been found that this averts the serious compressibility effects which arise at speeds approaching that of sound. Thus an aircraft with sweptback wings may be safely flown at a speed which would be dangerous if it were to have its wings at right-angles to the air flow. Since the A.W. 52 is only intended to travel at 500 m.p.h. its 'sweepback' may not be necessary from critical high-speed considerations, but as a research aircraft it will provide much valuable information on the use of 'sweepback' for higher speeds.

To reduce the remaining drag of the wing itself two notable developments of intensive research, laminar flow wings and boundary layer control, are incorporated in the A.W. 52. Over the last five years much attention has been devoted to the 'boundary layer' (the name given to the extremely thin layer of air adjacent to the wing surface) because it was found that the mode of flow of the general air stream was determined by what was happening to the boundary layer. If the particles of air in the boundary layer were sliding over each other, like a pack of cards pushed from one end, the flow was 'laminar' and followed the surface very well. Eddying or 'turbulent' flow in the boundary layer, however, led to a breakaway of flow from the surface, and the overall drag of the body was thereby increased. The point on the wing where the boundary layer changes from laminar to turbulent flow is called the transition point, and it was clear that the farther it occurred from the leading edge the lower was the drag of the wing. Special wing profiles were then developed which would give laminar boundary layers, but a variance of even a few hundredths of an inch from these profiles resulted in a turbulent boundary layer. Undaunted by these fine limits the makers of the A.W. 52 have produced a wing, the surface of which they claim to lie within those specified for laminar flow. The flight tests of this aircraft are thus very vital, as the success of its wing may provide the first confirmation of the laminar flow theory and prove that it is worth while to manufacture aircraft to such accurate limits.

Even when the boundary layer does break away it is possible to regain steady flow again by sucking it back

reichen, so erhält man ein höchst vollkommenes Analogon des Kekulé'schen Benzolsechsecks:

Fig. 1.

Nun aber besitzt der genannte Macacus cynocephalus ausser seinen eigentlichen vier Händen noch ein fünftes Greifwerkzeug in Form eines caudalen Appendix. Zieht man diesen mit in Betracht, dann gelingt es, die 6 Individuen des gezeichneten Ringes auch noch in anderer Weise mit einander zu verbinden. So entsteht das nachfolgende Bild:

Fig. 2.

Es erscheint mir nun höchst wahrscheinlich, dass die Analogie zwischen Macacus cynocephalus und dem Kohlenstoffatom eine voll-

FIG. 5.—Monkeying with the benzene ring. A spoof issue of *Berichte der Deutschen Chemischen Gesellschaft* advanced the theory that carbon atoms are analogous to monkeys, and though normally there are only four valencies they possess tails which can be brought into play to provide an extra valency.

to the wing surface. Boundary layer control by this means has been experimented with for many years, but again it reaches its first practical test in this aircraft, which has slots cut in the wing surface, to which suction can be applied from inside the wing. Information of the effect of this suction, especially on control at low speeds, is eagerly awaited.

Finally, this remarkable aircraft is jet-propelled, so that it may be possible to investigate a combination of gas-turbines and boundary layer suction, as the turbines need a tremendous quantity of air, which it could suck through the wing slots.

The A.W. 52 is thus a synthesis of recent aerodynamic advances, and under the new policy of the Ministry of Supply such new knowledge applied to aircraft design should be checked in flight on full-scale research aircraft as well as in the wind-tunnels. It will, therefore, act as a link between the fundamental research and the final operational aircraft. The building of the A.W. 52 was preceded by the construction (also by Armstrong-Whitworth) of a model glider which was flown successfully in 1946, and on which many measurements needed for the design of the A.W. 52 were made.

Humour in Chemistry

Oh, he who'd make his fellow, fellow, fellow
creatures wise
Should always gild the philosophic pill,

quoth Jester Jack Point in *The Yeomen of the Guard*. And so also thought Surgeon John Scoffern when he wished to teach his fellow creatures chemistry.

Therefore he wrote his book, *Chemistry No Mystery* (London, 1839), a pretended shorthand transcription of a course of lectures by an Old Philosopher to a literary and scientific institution in Devon. The text-book tells us that bismuth compounds turn black under the action of hydrogen sulphide. But the Old Philosopher makes sure we remember the fact by telling the story of the vain young lady. Like many of her time she gave herself a much desired white complexion by daubing her face with pearl white, one of these bithmuth compounds. She was foolish enough, however, to take a bath in the Harrogate waters, which are well impregnated with hydrogen sulphide, and (in the words of the O.P.) "her fair skin changed in an instant to the most jetty black . . . uttering a shriek, she is reported to have swooned".

The interesting physiological effect of nitrous oxide (laughing gas) are equally well impressed on the reader by the description of events which followed when the O.P. allowed his audience to breathe it; "Some jumped over the tables and chairs; some were bent upon making speeches; some were very much inclined to fight; and one young gentleman persisted in attempting to kiss the ladies. I have heard it insinuated that he breathed very little of the gas, and that he knew very well what he was doing . . . As our instructor predicted, we did not after this exhibition feel very much inclined to study philosophy, and therefore the Lecture, although short, was brought to a conclusion." George Cruickshank's illustration of this scene is reproduced on the opposite page. One feels that at least some parts of chemistry would have been firmly fixed in the minds of those imaginary Devonian listeners.

We repeat this story from Professor John Read's latest book, *Humour and Humanism in Chemistry* (Bell, London, 1947; pp. 388, 21*s*.). Professor Read evidently agrees with Jack Point on pedagogical questions. The book is not a formal history of chemistry; yet it is no mere collection of anecdotes. Between the lively stories there is packed a great deal of useful information on chemical-historical topics, which is not easily accessible elsewhere. There is, for example, a very useful analysis of Boerhaave's *Elementa Chimiae*, a book which exerted tremendous influence for nearly two generations, but which is usually given the briefest treatment in histories of chemistry because it happens to contain no great discoveries. There is, too, a delightful account of the doings of John Damian, court alchemist to James IV of Scotland (1488-1513), who was one of the most scientifically enlightened monarchs of his time. We get much fun from this story, but we also get, what is hard to come by, precise information on the working costs of alchemy *via* the Lord High Treasurer's Account Books.

The word 'Humanism' is used in the title of the book in

a rather narrow sense. The book is not notably concerned with the relations of science to society; rather it is concerned with showing that the people who made chemistry were 'human'. This accent on the personal humanity of chemists helps quite as much as the humour to gild the philosophic pill.

Let us end with what Professor Read regards as "the last expiring gasp" (at least inside professional literature) of humour in chemistry—a spoof issue in 1886 of the *Berichte der Deutschen Chemischen Gesellschaft* (Reports of the German Chemical Society). This issue appeared with a format identical with that of its genuine brother, except that its title was changed to *Berichte der Durstigen Chemischen Gesellschaft* (Reports of the Thirsty Chemical Society), and that 'Nineteenth Annual Issue' became 'Unheard-of Annual Issue'. The imitation was so perfect that the editor of a leading London chemical journal is said to have torn the issue into sections and sent these to his abstractors as usual. Among the remarkable scientific discoveries in this issue was a new theory of the benzene ring, whose nature is indicated by Fig. 5.

There was also a note on a method of avoiding the inconvenience arising from the great length of tube required for lecture demonstrations of the fact that water in deep layers has a blue colour. The suggested method is to add a little methylene blue to the water. "This little dodge," said the writer, "enables one to reduce the length of the apparatus considerably; indeed I have found it remarkably easy to demonstrate the required colour even in a simple test-tube. I can thus warmly recommend this form of the lecture experiment to all colleagues."

After 1886 increasing specialisation and professionalism have driven light-heartedness from the literature. But Professor Read believes that the growing importance of chemistry in daily life and the consequent demand for popularisation are once more giving an opportunity for the linking of chemistry and humour.

FIG. 6.—George Cruickshank's cartoon, 'Laughing Gas' (from John Scoffern's book, *Chemistry No Mystery*).

Bread and Canine Hysteria

SOME of the commentators in the daily press have been making rather wild statements about a 'poisonous' substance in bread. It is of interest, therefore, to summarise the true facts of the case.

For many years dogs have been known to suffer from a disease known as 'canine hysteria' which was characterised among other things by fits similar to those suffered by epileptics.

In 1946 Sir Edward Mellanby showed that these fits could be induced in dogs by feeding them a diet with a relatively high proportion of bread and that the harmful effect of the bread was due to the effect of what is called the 'Agene' process on the flour.

In this process, before making bread, flour is treated with nitrogen trichloride. The object is to hasten the maturity of the flour and thus improve the character and palatibility of the loaf. Last year Dr. T. Moran, director of the Flour Millers' Research Association, found that the nitrogen trichloride combines with the gluten, one of the proteins of wheat flour, to form a toxic substance. Neither nitrogen trichloride nor the gluten has any harmful effect when eaten separately. Results of American work have now come out and show that American bread also contains this toxic substance, and American scientists, notably Professor Elvejhem, have shown that this toxic substance will also produce nervous symptoms in cats and if it is fed to monkeys it produces weakness and tremors in them.

These results have naturally led to the fear that consumption of bread by human beings may produce toxic symptoms—but there is no evidence as yet that this is so. In fact, Professor Elvejhem investigated five healthy children in the U.S. who were eating bread, more than sufficient to cause hysteria in dogs, and could find no signs of nervous symptoms as a result. However, if consumed over a longer period, it seems that there might have been some effect. We in Great Britain have, however, been eating bread made from 'agenised' flour for 25 years, and no diseases directly attributable to the toxic substance have been noted. However, there exists the possibility that some diseases, and disorders of the digestive tract have been mentioned, may be due to long-continued eating of a diet containing a high percentage of bread. It will be very difficult in fact to prove that this toxic compound is not harmful to human beings, and it is noteworthy that the Food and Nutrition Board of the National Research Council of the U.S. has now (according to the *Lancet*) sent a letter to the Commission of Food and Drugs recommending a thorough investigation into alternatives to

FIG. 7.—The EDSAC Calculator under construction at the Cambridge University Mathematical Laboratory. The 'Memory' unit is complete and is seen as a long battery of tubes in front of the operator. Each tube is filled with mercury and stopped at each end with a quartz crystal. Impulses are transformed by the piezo-electric effect into supersonic vibrations in the quartz on entering the tubes. The quartz crystal at the far end re-converts them into electronic impulses which are collected, amplified, 'cleaned', and passed back into the tubes. The finished machine will have about 2000 valves.

nitrogen trichloride for bleaching bread. We can expect some similar action in Britain in due course.

Cambridge's High-speed Calculator

HIGH-SPEED electronic calculating machines have been much in the news. But it is perhaps not generally realised that in the whole of Europe only one machine has got past the project stage and is actually being built. This is the EDSAC—Electronic Delay Storage Automatic Calculator—at the Mathematical Laboratory of Cambridge University. Construction was started at the end of 1946, and it is hoped that the machine will be ready for testing this summer. Several electronic machines are being built in the U.S.A. and some information has been published about the EDVAC, now under construction at the Morse School of Electrical Engineering, Philadelphia, with which the EDSAC has some points in common. Mr. M. V. Wilkes, Director of the Cambridge laboratory, is at pains to emphasise that the machine is being kept as simple as possible—refinements and extensions can be added later.

The general way in which these automatic calculating machines work has been outlined by Dr. S. Lilley in DISCOVERY (January 1947, pp. 23–8) and we need not repeat that material now. The most interesting special feature about the present machine is its memory device, which can perhaps best be introduced by a parable concerning Professor F. Orget. The Professor's work is such that every day he acquires certain data, which he has to keep on tap until he wants it for further work at some unspecified time in the future. His memory is very bad, and he cannot trust himself to use a filing system. He has, therefore, hit upon the following plan. Whenever he discovers a fact that must be remembered, he writes it down and posts it to a friend in the U.S.A. By a standing arrangement, this friend immediately re-directs the letter to the Professor. And so, a few days later, the important data turns up again at the Professor's breakfast table. If he is now ready to use the material, he does so; if not, he immediately posts it off again to his American friend. By this device he is able to keep a vast amount of data in circulation, each item turning up regularly, to be withdrawn and used, or re-circulated, as the situation requires. EDSAC's memory is an electronic adaptation of the Professor's system. The numbers which the machine has to remember take the form of patterns of electrical pulses, which are transmitted from one part of the machine to another by a system of wires and valves. There are two ways in which one can arrange for a machine to remember such a number. In the first the pulses are used to put some element of the machine into a particular state; the element stays in that state until it gets a further signal which causes it to send out a pattern of pulses corresponding to those it originally received—for example, the pulse might be used to stimulate one or more trigger circuits, which will remain in an excited state until the data is required, as is done in ENIAC. On the other hand it would be more convenient if the pulses could be kept all the time in the form of pulses until needed. But pulses are essentially dynamic things and can only be kept at all if they are kept in circulation—like the Professor's letters. The speed with which pulses travel in an electric circuit is, however, much too great; and some method of slowing down their rate of circulation must be found. This is done by transforming them, at one stage of their travels, into pulses of supersonic waves, which travel much more slowly, and later changing them back again into electrical form. The memory unit consists of a number of tubes (seen in the foreground of our photograph), each filled with mercury and stopped at the ends with quartz crystals. The crystal at the input end changes the electrical pulses by means of the piezo-electric effect into supersonic pulses which travel through the mercury at the speed of sound. The output quartz crystal re-converts the pulses to electrical form, after which they are amplified, 'cleaned', and passed back to the input end. Thus the impulses will keep on circulating, until a particular instruction arrives to divert them for use elsewhere in the machine. Each tube can deal with 16 numbers of 10 decimal places, circulating behind one another something like the animals in Alice's Dodo race. Altogether the machine has a memory capacity for about 500 numbers of 10 decimal places.

The machine will do some 10,000 operations a minute. The initial numbers which the machine has to use in a calculation are fed into it as rows of holes punched in a teleprinter tape. Operating instructions, telling the machine what to do with these numbers and with the further numbers that it calculates for them, are themselves translated by a code into numbers punched on the tape and fed in along with the 'real' numbers. Thus there is no preliminary setting-up process—once the tape has been punched and fed in, the machine does all the rest.

Mr. Ritchie Calder, well-known science editor of the *News Chronicle*, went to the Unesco Conference in Mexico City as a member of the British delegation. One of the keenest publicists of Unesco, in this article he expresses forcibly and critically his views upon the salient points that emerged from the conference: in particular he focuses attention upon the urgent need for Unesco to reach the common people throughout the world and gain their support.

Science is Unesco's Strong Point

RITCHIE CALDER

If only we had paid more heed to Dr. Carlos Monge, the delegate from Peru, the Unesco Conference, at Mexico City, might have achieved even better results. With evangelical persistence, this physiologist from the University of San Marcos kept on reminding delegates of the facts of life at high altitudes.

On the opening day, when most of the delegates breathlessly mounted the rostrum of the Escuela Normal, to pay compliments to their Mexican hosts, the Peruvian made it the occasion for a discourse on the effects of high altitude on reproduction. In the science working party, Dr. Monge, who was rapporteur, supplemented his report with a paper on the physiological differences between Andean Indians and the rest of the human species. If he encountered a colleague in the colonnade, he would buttonhole him with an earnest plea for a Unesco project on behalf of the 28,000,000 people in the world who live above the normal atmosphere.

In their own interests, delegates should have harkened more attentively than they did. If 'reproduction at high altitudes' became a standing joke at cocktail parties, 'production at high altitudes' was no joke at all. We were working at an altitude of 8,000 ft., and the effects, though insidious, were definite. The thin air produced anoxia, dulling our wits and sharpening our tempers.

All the same, the Mexican Plateau was not entirely responsible for the exasperation (in three languages) of the delegates at the delays which wasted half the Conference. The Unesco secretariat ought to learn that it can expect no sympathy if it gathers expensive delegations from the ends of the earth and confronts them with an unworkable programme and an unmanageable agenda. For instance, at Mexico, it introduced a system of 'working parties', recruited from the experts attending the conference. The science working party, for example, was to examine in detail the grants-in-aid to the International Scientific Unions, the Hylean Amazon project, the system of Unesco field officers, and the social implications of science. Such working parties met simultaneously with the Programme and Budget Commission which was considering how much Unesco was to be allowed to spend and on what projects it could spend it. But the working parties had no status in the conference; their purpose was to help, by a consensus of experience, the secretariat to carry out the projects sanctioned by the Conference. But the working parties could not know what projects the Programme and Budget Commission would approve, and the Commission could not know what projects to approve without the advice of its experts, *i.e.* on the working parties. So, after days of wrestling with this paradox, the Programme Commission had to decide to wait and consider the reports of the working parties.

That sort of thing is 'kitchen stuff' and, some would say, remote from the high objects and high ideals of Unesco, but it is, perversely, very important. It explains, in part, why the Unesco Conference had a 'bad press', or, in this country, practically no press at all. Readers are not interested in procedure and, after a fortnight of dithering, the Conference had ceased to be current 'copy'; concrete results were lost, as far as the newspaper men were concerned, in formulation; and the best that even sympathetic journals could afford to give about Unesco were belated 'round-ups'.

A Million Dollars Unspent

And it was the sort of experience which made delegations scrutinise very closely the workings of Unesco. Why, with so much to do and with only six and a half million dollars with which to do it, did Unesco finish up its first year with a million dollars unspent? (That is not economy; there is no carry-over and that million is written off.) Why, out of what was spent, did so much go on administrative costs at the expense of the practical programmes which are the reason for Unesco's existence? Why were the heads of the programme sections subordinate to, and at the mercy of, administrators who, after all, are only the housekeepers? Why, on the showing of a disappointing year, had creative enterprise been stifled? Why had Unesco failed to 'get across' and capture the imagination of the mass of the people, to whose service it is dedicated?

Of course, there was the excuse that it was the first year's work, but representatives of 40 countries were there to plan and finance the programme for the second year, and they were justified in insisting that the manifest faults should be put right. Of course, it could be argued that Unesco had to prove that it was a business concern, but a business exists to produce results and is not run for the benefit of the book-keepers. As it was, the Conference finally budgeted seven and a half million dollars for 1948, with the insistence that the administrative balance should be redressed in favour of the programme sections. An increase of one and a quarter millions was much less than would have been necessary for the expanding programme which we foresaw the year before.

Without question, the section which had proved itself the most efficient both in execution of its 1947 programme and in its proposals for 1948, was the science section. Some of the delegations were suspicious of the amount which was being spent on science. They were dubious, for example, about the grants-in-aid to the Scientific Unions. The experts on the working party were instructed to examine and curtail. They examined and confirmed.

The explanation, of course, is that in science Unesco, as

in no other field, took over a 'going concern'. It did not have to create machinery—that already existed in the shape of the international congresses in practically every branch of pure science; it did not need to provide even the fuel; all it had to do was to provide lubricating oil to make the machinery run more smoothly. It had also to encourage applied science and technology to create unions similar to the pure sciences.

The Hylean Project

Some dubiety was also expressed (and removed) about the Hylean Amazon project. This was initiated at the first Unesco Conference in Paris from an offer by Brazil to make available an institute, at Belem, as an international centre for the study of the problems of the Amazon area. That embraces a third of the continent of South America and involves seven sovereign states and three European dependencies—the Guianas. It is largely unexplored and there is little systematic knowledge about its natural characteristics. About 200,000 natives are supposed to be scattered throughout the vast area. There is the obvious wealth of timber and convertible vegetation. There is the uncharted mineral wealth of which the gold, diamonds, etc., of the Guianas are just a hint.

Humboldt, the German explorer and naturalist, called it 'Hylea' 130 years ago. Since then explorers have skirmished in the area. Weird tales have been written in serious works as well as in the 'penny-bloods'. Air lines ply across it and see only a closely-knit carpet of green, but where is the bulldozer which could drive a path through?

Some of us thought it exciting. Or it could be made so and, heaven knows, Unesco needs something colourful to catch the public imagination. Others thought it too ambitious for Unesco with its limited resources. Others asked why the countries concerned could not join up and tackle the problems and share the cost. That was missing the whole point; it is not just a Pan-Hylean project but an international one to establish a lien on the development of this area not merely for the governments concerned but for the people of the area and the benefit of the whole world.

To begin with, it would be the hunting-ground of the 'ologists'—anthropologists, zoologists, archaeologists, climatologists, geologists, mineralogists, etc. That would be the Unesco phase of research and inquiry. But the plain '-ists' would move in later—the arborists, agriculturists, nutritionists, the applied chemists and, maybe, pilot industrialists under the aegis of the Food and Agriculture Organisation, to work out methods of sane development. Then the expansionist period would come with the help of the International Bank, the Monetary Fund, etc. It could be a United Nations' T.V.A.

A pipe-dream, perhaps. But all that Unesco was being asked to do was to endorse a conference of international experts which had already met at Belem and had agreed on the initial steps. Unesco was to make a contribution to the initial expenses, the bulk of which was to be subscribed by the governments of the ten countries, with Brazil weighing-in with a handsome financial offer. The scientists in Unesco had no doubts about the virtues of the scheme as a means of acquiring knowledge; and we managed to raise 100,000 dollars for 1948, partly by transferring to the project temporarily the funds and field officers who had already been sanctioned for Latin America. (Scientific field offices for the exchange of scientific information and assistance have now been established by Unesco in the Middle East, Far East and southern Asia, as well as Latin America.) That is not an excessive premium to pay as 'key-money' for international access to a third of a continent.

Need for Popular Support

Apart from its scientific value, just think how Hylean Amazon might help Unesco to capture the popular imagination. To make it so, should be a priority job for the 'Ideas Bureau' for which the British delegation asked half-a-million dollars.

That Bureau had been one of the major issues of the Conference. (There were no real struggles in the science discussions; Dr. Needham had done such a workmanlike job and, anyway, the Scientific Intèrnational already exists with scientific delegates talking, if not a common language, always a common idiom.) The British case was unanswerable. Unesco, even as a trade-mark, has not produced any impact on even a tiny fraction of the 2,000 million ordinary people in the world. Until it does, it will not be able to influence or enlighten, and it will not be able to get a budget commensurate with its tasks. Until there is popular support for Unesco there will be no political incentive to governments to spend money on it.

Anyway, Unesco does not exist as a get-together of specialists. Scientists, educationists and the exponents of the creative arts who come together under the auspices of Unesco do not do so for their own edification but for the advancement and enlightenment of the common people; they are only a means to an end. Therefore, we argued—and the Conference supported us—Unesco must get down into the market-place, into the firesides, into the cinemas and the buses. Before it can instruct, it has to attract. It has to become 'box-office', not to the detriment but to the advancement of its higher objects. It has to be two things at once: it has to be the People's Palace as well as the Aeolian Hall; the Light Programme as well as the Third Programme; the bazaar story-teller as well as Education in World Citizenship; Greer Garson as 'Madame Curie' as well as international cartography.

Conversely, the instruments of press, film and radio by which Unesco can reach out to the people, are at the moment, by fault or default, the instruments which are sowing misunderstanding and distrust, destroying the very internationalism which Unesco is supposed to promote.

What is the good, we pointed out, of earnest inquiries, surveys and even programmes of scientific development, if Unesco, through lack of popular support, cannot secure the means to implement the results; if, in a few years' time, Unesco does not exist. So we proposed an 'Ideas Bureau' and, among other projects, a 'World University of the Air'.

Function of the 'Ideas Bureau'

The 'Ideas Bureau' will be a small group of ingenious persons who will be continuously casting around for examples which already exist of human co-operation and

[Continued on p. 51

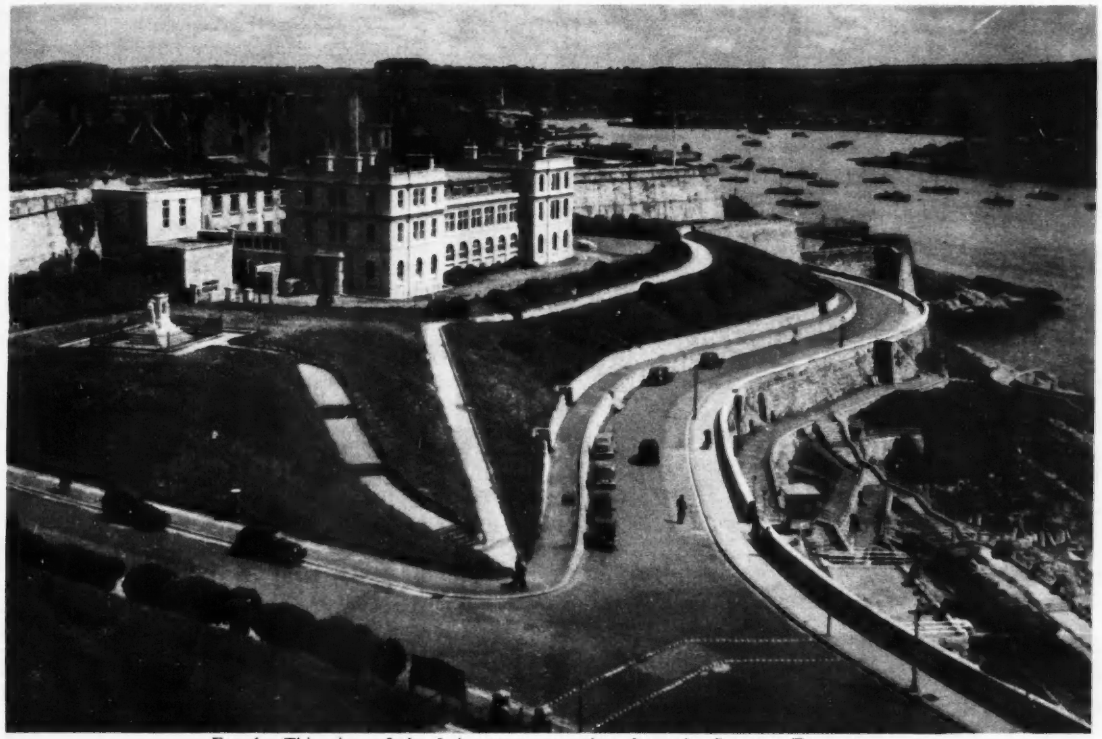


FIG. 1.—This view of the Laboratory was taken from the Smeaton Tower on Plymouth Hoe looking eastwards towards the Cattewater.

FAMOUS RESEARCH INSTITUTIONS—VII

The Plymouth Marine Biological Laboratory

G. A. STEVEN, B.Sc., F.R.S.E., R.N.V.S.R.

THE scientific study of the sea and its amazing wealth of life is of a very recent origin, dating roughly from about the middle of last century when a few tentative voyages of exploration were made. Until that time it was believed, even by the highest authorities, that marine organisms were confined to depths of 300 fathoms and less, and that all the vast sea world below that level was a sepulchral realm of absolute and everlasting calm and silence, permanent darkness and intense cold, in which no living thing could possibly exist. But in the year 1868 H.M.S. *Lightning* proved beyond all doubt the fallacy of this belief by dredging up from 650 fathoms a rich collection of marine animals, many of them wonderfully constructed organisms that had never been seen before. It was not, however, until the return of the famous *Challenger* expedition (1872-6), under the leadership of Sir Wyville Thomson, that the great world of the ocean floor was clearly revealed. During her three-and-a-half years' voyage of exploration the *Challenger* cruised over 68,900 nautical miles, dredged new and rare forms of life from 354 stations situated in all the oceans, many hauls bringing up bizarre creatures from depths of over five miles. It has even been said that the science of oceanography was born at sea on February 15, 1873, at the first official dredging of the *Challenger* expedition. It is at any rate certain that this great expedition raised a wave of enthusiasm which has since beaten on the shores of many lands and stimulated marine biological and oceanographical research in almost every part of the world.

But marine expeditions, however large and well found, are necessarily limited in the scope and type of work that they can successfully accomplish. Detailed study of the data acquired and the material collected at sea can be satisfactorily carried out only in suitably equipped laboratories on shore. Only in such laboratories, too, situated on the sea-coast where marine animals and plants are easily obtained and can be kept alive in aquaria, is it possible to proceed beyond the study of form and structure and attack the more difficult problems of function and habit.

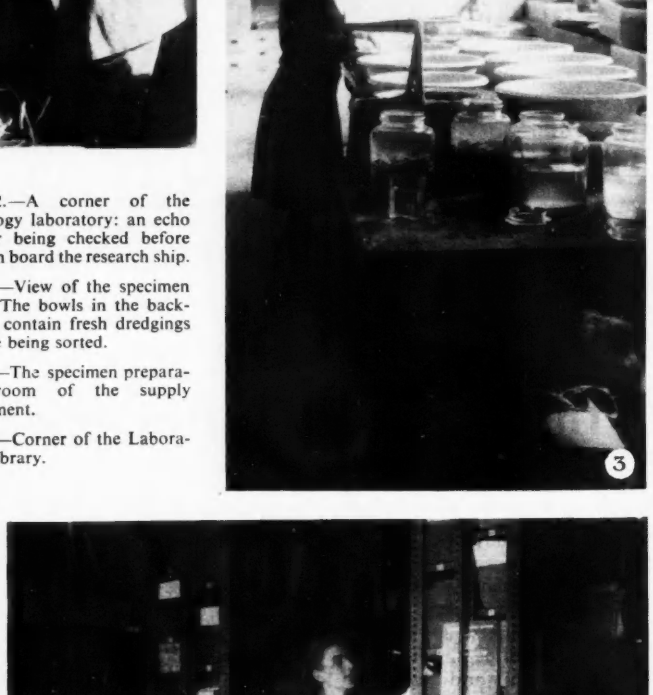
The need for such laboratories has resulted in the foundation of marine stations in most parts of the world. Organised expeditions, of course, are still necessary, but their work in future will be designed to extend and supplement

FIG. 2.—A corner of the physiology laboratory: an echo sounder being checked before going on board the research ship.

FIG. 3.—View of the specimen room. The bowls in the background contain fresh dredgings that are being sorted.

FIG. 4.—The specimen preparation room of the supply department.

FIG. 5.—Corner of the Laboratory's library.



the work of shore establishments rather than to serve as an end in themselves.

In the year 1872 the celebrated Marine Biological Station at Naples was founded by the eminent naturalist, Dr. Anton Dohrn. This was—and perhaps is still—the best known of all the marine laboratories in the world. Few of the great biologists of the last fifty years have not worked at Naples. To Scotland falls the honour of starting the first marine biological laboratory in Great Britain. In 1883 the Scottish Fishery Board fitted out a small laboratory at St. Andrews where much useful research was carried on until the station was transferred to Aberdeen—where it still remains.

In 1884, a small laboratory was established at Granton in an old quarry, under the auspices of the Scottish Meteorological Society. The laboratory itself was a floating one, made out of an old boat, and named the *Ark*. After a time the *Ark* was transferred to Millport in the Firth of Clyde where it remained until the present Biological Station was built there. This station, now the laboratory of the Scottish Marine Biological Association, manned by a small staff and equipped with a powerful motor research vessel, is actively engaged mainly upon the study of seasonal fluctuations in the plankton (or drifting life in the sea) and the physical and chemical conditions that control it.

The Founding of the Laboratory

In 1884, when the *Ark* was still at Granton, the Marine Biological Association of the United Kingdom was formed with the object of founding an adequate marine laboratory on the English coast. Plymouth was selected as the most suitable site, and the Plymouth laboratory, the largest in our country, was in working order in 1887. It has since then been extended several times and is now one of the leading institutions of its kind in the world. The Marine Biological Association is a corporate body of subscribing members including naturalists and others interested in some or all of the many branches of marine research. It came into being when, through the energy and enthusiasm of the late Sir E. Ray Lankester, a meeting was held in the rooms of the Royal Society of London at which the chair was taken by Thomas Henry Huxley, at that time President of the Royal Society. The meeting was attended by many of the leading scientific men of that day, including Sir John Lubbock (afterwards Lord Avebury) and Sir Joseph Hooker as well as a number of other public men interested in the sea fisheries of Great Britain.

The aim of the founders is well expressed in the first resolution adopted by this meeting in which is emphasised the necessity for establishing one or more laboratories on the British coast "where accurate researches may be carried on leading to the improvement of zoological and botanical science, and to an increase in our knowledge as to the food, life conditions and habits of British food fishes and of molluscs in particular, and the animal and vegetable resources of the sea in general".

This wise and comprehensive policy has been consistently followed by the Association throughout its entire history, its energies and resources having been concentrated mainly upon researches of a fundamental nature concerning the animals, plants and conditions of life in the sea. At the same time many investigations having a direct bearing upon immediate economic problems have also been carried on side by side with what may be called research in pure science, and—needless to say—the two have immensely helped and supported each other.

The laboratory, which is now the main south building, was officially opened on June 30, 1888, the original building and fittings having cost some £12,000. Since that time the sum of over £23,000 has been spent on various extensions that now form the north block containing the chemical and physiological sections, underneath which are cellars excavated out of solid rock. These cellars, because of their low range of temperature change and their freedom from vibration are extremely well suited for researches requiring very delicately adjusted apparatus.

The two upper floors of the south building are divided into research rooms in which rather more than twenty research workers can be accommodated. In the north block provision can be made for about sixteen workers, so that the whole Laboratory can take in about forty investigators at one time, including the permanent scientific staff which at present numbers twelve. The ground floor of the south building houses the Laboratory's aquarium.

Support from the Government

During its early years the Laboratory depended mainly on contributions from voluntary subscribers, and on grants from the Fishmongers' Company, universities, colleges and scientific societies for its annual income. From its inception it received also an annual grant from H.M. Government which during its first years amounted to only £500. This grant was then increased to £1000, at which figure it remained for many years. In 1902 the Association was asked to undertake the English share of the programme of international investigations formulated by the International Council for the Exploration of the Sea—an organisation consisting of representatives of all the nations bordering on the North Sea, and to which the British Government had adhered with a view to co-operating with other European countries in a comprehensive programme of research into the natural history of the marketable marine fishes. For this work, which continued in the hands of the Association until 1910, an auxiliary laboratory was established at Lowestoft and—due largely to the generosity of a private subscriber—a steam trawler was acquired for work at sea.

From 1910 till the outbreak of the 1914-18 war the English share of the International Council's investigations were carried out by the Ministry of Agriculture and Fisheries, with London as the administrative and scientific headquarters; but on resumption of work after peace was declared the laboratory at Lowestoft was taken over by the Ministry and re-opened for the purpose of studying problems having a direct bearing upon the commercial fisheries.

At the same time a substantially increased Government grant was made to the Marine Biological Association for the maintenance of the Plymouth Laboratory so that researches of a more general and fundamental nature concerning life in the sea might be developed there on a broader plan. With the help of this larger grant the steamer

Salpa, a drifter-trawler of 90 tons, was purchased by the Association for service at Plymouth to replace the S.Y. *Oithona* which had done valuable service in the Laboratory's earlier days. Subsequently a motor launch was built for work in inshore waters. This launch, the *Gammarus*, is still in service but the *Salpa*, after having been on requisition-charter for naval duties during the recent war, has had to be sold. Her place has been taken by an ex-Admiralty motor fishing vessel, a 90 ft. diesel-engined ship, now registered as the *R.V. Sabella*.

The first director of the Plymouth Laboratory was G. C. Bourne (1887-90). The periods in which his successors held the appointment were as follows: W. L. Calderwood (1890-3), E. J. Bles (1893-4), E. J. Allen (1894-1936), S. W. Kemp (1936-45), F. S. Russell (1945-).

Almost every problem connected with the sea and the organisms it contains falls within the scope of the researches at Plymouth. The results of these investigations are published in the Association's own 'Journal'. But probably an even larger number of scientific contributions to knowledge—chiefly by visiting investigators—appear in the transactions and proceedings of learned societies and in scientific periodicals.*

In addition to the ordinary work of research, the duties of the Laboratory's scientific and technical staff include the collection and preservation of marine animals to supply the requirements of museums and biological departments of universities and colleges all over the world, and the formation and upkeep of a type museum of the marine fauna of the Plymouth area. They also undertake to supply the plants, animals and water samples required by visiting scientists for any approved investigation or to provide such facilities for obtaining them as may be at the command of the Laboratory.

FIG. 6.—Hauling beam trawl on the Laboratory's Research Launch *Gammarus*. Near the camera is Mr. Bill Searle, who has been on the staff for over fifty years and is well known to many biologists all over the world.

The accommodation provided for visitors includes separate rooms and bench space, with adequate fittings for biochemical and physiological work, and the use of all ordinary glassware, chemicals and apparatus. The Laboratory is open night and day for research by visitors and others throughout the entire year, including holiday periods.

These facilities for research supplied by the Plymouth Laboratory are in constant demand by an ever increasing number of visiting scientists—both British and foreign. During the inter-war period the international character of the work steadily and rapidly expanded. In a typical inter-war year, in addition to British workers, the visiting scientists who worked at the Plymouth Laboratory were drawn from Canada, New Zealand, Australia, India, Ceylon, Japan, Spain, Poland, Denmark, France, Holland and Hungary.

The personal contacts thus established with research workers from other centres both at home and abroad are of inestimable benefit to both resident staff and visitors alike. In addition to those who come to work on some particular problem, the results of which are later published, there is always a steady stream of visitors from all countries who come for brief periods to discuss with the staff special points appertaining to their own researches, or to make themselves familiar with important advances in one or other of the various investigations in progress.

When the Marine Biological Association was formed, marine biology was still in its infancy. Little or nothing was known of the fauna and flora of the British seas. The early activities of the Plymouth Laboratory were therefore largely devoted to dredging, trawling and tow-netting in order to obtain accurate information concerning the occurrence, distribution and habits of the invertebrate inhabitants of the surrounding waters, to building up a type museum, and to studying and classifying the bottom deposits. In 1904 a 'Plymouth Marine (invertebrate) Fauna' was published in the Association's Journal. This 'Fauna List' proved of great and immediate benefit to all students, teachers and research workers in invertebrate zoology. A second and much larger edition embodying the records compiled in the intervening years was issued in 1931 as a separate publication in which the fishes of the area are also included.

Such work, however, though a necessary foundation, was only part of a larger plan, clearly comprehended from the very beginning, but whose development could be only gradual, is in fact still unfolding and whose end no one yet can see.

* A complete list of publications recording the results of researches carried out under the auspices of the Marine Biological Association in their laboratory at Plymouth or on the North Sea Coast from 1886-1927 was published in the *Journal of the Marine Biological Association*, 1928, Vol. XV, No. 3. It is hoped to bring the list up to date in a further publication in the near future. A general description of the laboratory and its activities is given in Mr. F. S. Russell's lecture, published since this article was written, in the *Proceedings of the Royal Society*, Series B, 1947, Vol. 135, No. 878, pp. 12-24.

No study of marine animals can proceed very far without a knowledge of the medium in which they live—the sea itself. Certain, if not all of the chemical and physical properties of sea water have an important influence—directly or indirectly—upon the whole flora and fauna of the sea. Much work has been done, in many centres in numerous countries, on the chemistry, physics and hydrodynamics of sea water all of which has combined to swell the sum of human knowledge concerning them. A very large number of important contributions has emanated from Plymouth.

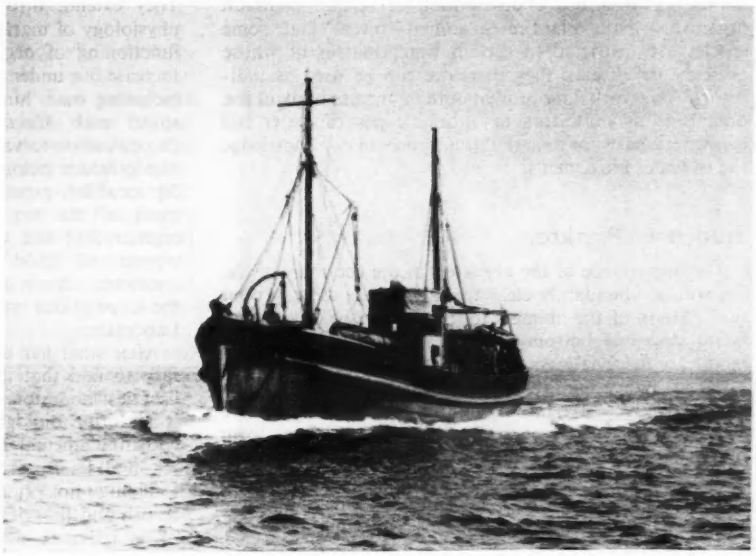


FIG. 7.—Research Vessel *Sabella* returning from sea.

In the sea, as on the land, the basic end of all the food chains consists of plants—most of them tiny organisms that float in the upper layers and are known collectively as phytoplankton. Each tiny plant is short-lived but reproduces itself at a rapid rate when food in the form of dissolved nutrient salts—phosphates, nitrates, silicon and trace elements such as iron and manganese—are plentiful and the sun's energy is strong enough for active photosynthesis. During the winter months, except in low latitudes, the phytoplankton dies down, therefore, to a minimum because there is so much vertical mixing due to wave action that it cannot remain constantly enough in the rather shallow surface layer illuminated by the winter sun. But at the approach of spring with its longer and stronger daylight and calmer seas the phytoplankton organisms multiply with extreme rapidity.

Chemistry of Sea Water

The size of the plant crop is then limited by the amount of nutrient salts present. When some essential ingredient is used up the crop dies down. Much of it is eaten by tiny planktonic animals (zooplankton); much dies and sinks to the bottom where it forms or augments the food of bottom-dwelling animals.

While these tiny plants are flourishing in the spring there is at the same time a great increase in the numbers of the zooplankton. Many of these feed directly on the plants; they in turn fall a prey to larger carnivorous forms and so the chain continues right up to the economic species of fish, crustacea and molluscs that form so valuable a part of our food supply—especially at this time.

In studying the economy of the sea, therefore, it is necessary to be able to estimate quickly and easily the quantities of nutrient salts available in different bodies of water and to follow the changes they undergo throughout the seasons in relation to the plant crop. Chief amongst these nutrients are the nitrates and phosphates, the determination of which at one time entailed very elaborate and lengthy processes. Routine determinations in numerous samples of water were therefore quite impossible and a useful overall picture hard to obtain.

At the Plymouth Laboratory improved methods of both nitrate and phosphate determination were devised which are not only more quickly and easily carried out but also considerably more accurate. They have therefore been adopted by marine workers all over the world. Even so, the methods are not yet all that can be desired, and the work of improving them or of finding new ones is still going actively forward.

The trace elements are even more difficult to deal with but considerable progress is now being made towards determining the parts played by certain of them—e.g. manganese and iron. The techniques involved are so delicate that a long time must elapse before anything like an adequate understanding of them can be expected.

Even when all the nutrients are present in plenty, photosynthetic activity is governed by the amount of light that can penetrate to various depths. Very delicate and reliable methods of determining light intensity by photo-electric means have been devised and perfected at Plymouth, whose 'light work' has formed the foundation for similar researches in other laboratories all over the world.

In very small enclosed bodies of water nutrient salts can be added successfully by artificial means to replenish those used up by the activities of the phytoplankton. In the sea this cannot be done and replenishment of the upper layers impoverished by plant growth can take place only by the upwelling of richer waters from below, as deep ocean currents impinge upon the edges of the continental shelf, or are brought up from lesser depths by wave action or other water disturbances.

The horizontal and vertical movements of water masses must therefore be known and followed closely. For this the identification of different water masses is of vital importance. To some extent this can be achieved by accurate determinations of temperature, salinity and oxygen content, but the time and labour required for such work on any considerable scale are immense. But observations

on the occurrence and distribution of certain plankton organisms—both plant and animal—reveal that some species are restricted to certain water masses of whose presence or absence they therefore can be used as indicators. The work done at Plymouth on the use of plankton organisms as indicators of various types of water has formed the basis for remarkable advances in our knowledge the of water movements.

Studies of Plankton

The importance of the plankton in the economy of the sea will be abundantly clear from what has already been said. Many of the animals forming the zooplankton are larval stages of bottom-dwelling species. These pelagic larvae are nearly always so different from the adults as to give no indication at all of their parentage. Much painstaking research at Plymouth has been devoted to following the development of marine invertebrates from the egg to the adult in order to assign the correct names and systematic positions to unknown larvae. The list of identifiable larval forms is now a long one, but large numbers remain whose parentage is still unknown. So work goes on.

Physiology of Marine Animals

Although the productivity of the sea begins in its upper layers it extends from surface to bottom, and biological study of the invertebrate bottom fauna has always occupied a prominent place in the Laboratory's programme of research. These researches cover a very wide field, having a bearing upon the economy of the sea in all its aspects. Their importance, however, is not confined to the sea. They extend, through researches into the comparative physiology of marine animals, to specialised study of the functioning of organs and tissues the results of which increase our understanding of such activities in all animals including man himself. Nerve-muscle reactions in the spider crab *Maia*, the response of muscle tissues of *Phascolosoma* to various drugs (*Phascolosoma* is a worm-like creature belonging to the group of animals called Sipunculids), experiments in fertilisation and development of the sea urchins *Echinus* and *Psammechinus*, regeneration and other studies of giant nerve fibres in worms and squid, the functioning of the nerve net in anemones—these are but a few examples that illustrate the scope of this type of work carried out at the Plymouth Laboratory.

After what has been written above it is scarcely necessary to add that the Plymouth Laboratory is neither a fisheries laboratory nor an oceanographical institute. It is a Marine Biological Laboratory whose first concern is with fundamental researches into the productivity of the sea in all its aspects and problems arising therefrom.

Though not primarily and directly interested, therefore, in fish and fisheries these are not omitted from the range of its activities. Much useful research on the important subject of age and growth-rate in fishes has been and is still being done there. Following the publication in 1898 by a German worker called Holbauer of a paper in which he showed that the age of fresh-water carp could be determined from markings on its scales, Stuart Thomson, working at Plymouth, demonstrated for the first time that the same method was applicable also to various marine fishes. The great and valuable researches into the life-histories and growth-rates of food and other fishes all over the world owe much to the possibilities of advance opened up by these discoveries.

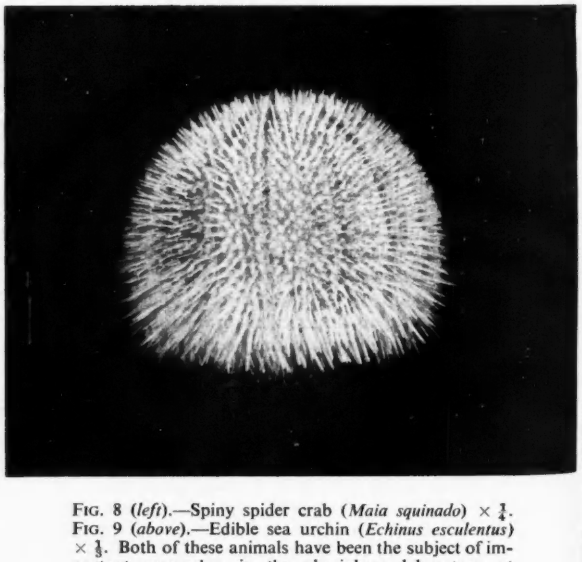


FIG. 8 (*left*).—Spiny spider crab (*Maia squinado*) × ¾.
FIG. 9 (*above*).—Edible sea urchin (*Echinus esculentus*) × ⅔. Both of these animals have been the subject of important researches in the physiology laboratory at Plymouth.

Fishery Problems

Fishery research has now reached a stage where the large and important fluctuations that take place in fish populations can be forecast for a number of food fishes with useful accuracy. But the causes underlying those fluctuations are still not fully understood, nor will they be until our fundamental knowledge of the complicated changes that take place in marine water masses is greatly extended. All the manifold activities of the Plymouth Laboratory combine to achieve this end. Thus, although it is not primarily a fisheries laboratory, in that its researches are not confined mainly to matters obviously connected with fish, the investigations carried out by its staff are of fundamental importance to long-range fisheries research.

Direct investigation of certain fisheries problems are, however, also carried out from time to time as the need for them arises. In the latter years of the herring fisheries at Plymouth tentative forecasts of the season's prospects were provided for the industry although fishery forecasting was then in its infancy. Researches into the life-history of the mackerel are at present in progress, and investigations into the depredations of seals and sea birds on the fishing grounds have also been carried out from time to time.

Perhaps the most interesting piece of fisheries work of direct economic importance ever carried to an outstandingly successful conclusion by the Plymouth staff was done as long ago as 1903. For many years previous to this date dogfishes—a kind of small shark—had been an endless source of inconvenience and loss to fishermen. They were themselves useless for market and interfered very greatly with drift-net fishing for herring, pilchards and mackerel. Although complaints had been made to fishery authorities with monotonous regularity year after year, it was not until 1903 that the problem was seriously studied and methods proposed for the removal of the scourge. In England the pelagic fisheries of the English Channel were most affected and the assistance of the Plymouth Laboratory was asked by the Sea Fisheries Committees of Devon and Cornwall to find and recommend remedial measures. After various means of exterminating the offender were considered and rejected, it was decided that the best way of achieving this end was to encourage the capture of dogfish by creating a market for them as a food commodity. In co-operation with the fishermen, the Fisheries Committees and other interested bodies, numerous experiments in catching, preparing and cooking dogfish were conducted and an extensive propaganda campaign was launched. Success was achieved and dogfish under the trade name of 'flake' gradually found a sale. Its popularity grew, and not many years elapsed before 'dogging' was a regular and profitable industry in the west of England; so much so that when in due course a scarcity of dogfish was encountered the fishermen bewailed their absence as whole-heartedly as previously they had deplored their presence.

Judged by some standards the Marine Biological Association's Laboratory at Plymouth is of no great size and its staff is very small. But the place it occupies in the forefront of marine biological investigation, both national and international, is the true measure of its scientific importance. In addition to its direct contributions to our knowledge of the sea and its inhabitants, it indirectly makes world-wide

FIG. 10.—Mr. F. S. Russell, F.R.S., director of the Laboratory since 1945. Mr. Russell served with the R.A.F. during the last war, when this photograph was taken.

contributions of no less value. Many of the techniques developed at Plymouth have been adopted by marine investigators in most other laboratories and by the scientific staffs of oceanographical expeditions who must perforce make use of techniques that have been already tried and tested and their possibilities and limitations accurately known.

Over and above its ordinary work the Laboratory also serves as an important centre for the general training of young biologists. Valuable facilities are provided for post-graduate research, and courses of instruction are arranged for senior students from universities and schools during the Easter vacation. The biology staffs of most colleges and universities and not a few schools in this country include one or more members who have worked at Plymouth either before or after graduation. The Laboratory's aquarium, open to the general public, is visited by large numbers of persons from far and near and serves to stimulate public interest in both marine and general biology.

The Laboratory buildings and all the aquarium tanks were very extensively damaged in the 'blitzes' on Plymouth. Much of this damage has already been repaired, but the eastern wing of the main building, which was completely burned out, is not yet restored. This wing, at the time of its destruction, was the Director's residence. It is being re-built not as a residence but as additional laboratory accommodation so that the Association's expanding activities may be adequately provided for. Fortunately, the very valuable library was removed to a place of safety and escaped damage.

(*Fig.* 1 *is from a photograph by Miss E. J. Batham; Douglas P. Wilson provided the photographs for Figs.* 6, 8 *and* 9. *The rest of the photographs were provided by the author.*)

The Need for Regional Weather Forecasts

PROF. DAVID L. LINTON

EVERYONE knows that Hollywood owes its film industry to the sunny, dependable climate of Southern California: and everyone knows, too, that before the days of humidifiers the moist air of Lancashire was among the natural advantages on which its cotton industry grew to world supremacy. Climate and weather are natural resources, and it behoves us to see that we use them to best advantage. Agriculture all over the world is, of course, highly adapted and adjusted to local climate and weather, but industrial undertakings and transportation systems have commonly to be operated under conditions which are decidedly adverse. This is invariably costly—whether the reckoning be in money, labour or plant—and in an economic system already strained by political considerations and world shortages such additional cost may well prove critical—a last straw which may break the camel's back. Such was nearly the case in Britain in 1947. The reappearance of mass employment, the loss of factory production, and the disorganisation of public life, consequent upon the fuel crisis precipitated by the severe weather of last winter, are too vividly remembered by everyone to need emphasis here.

Potato rationing in November 1947 came as the direct consequence of the flooding of Fenland farms six or seven months earlier, and our continuing shortage of milk results from the ill effects of the late summer drought upon grass and fodder crops. That same drought threatened the Manchester populace with the dismal prospect of drawing water from standpipes in the street and saddled their Corporation with the expense of assembling a fleet of 200 army water trucks and converting 100 lorries to water carrying; the need to use them, however, was averted by a species of miraculous reprieve—a fall of 2½ inches of rain in one day in the Pennine catchment areas. The weather of 1947, in fact, must have convinced even the least weather-conscious town-dweller that there is still much in our elaborate urban civilisation that is highly dependent upon the weather, and much that is singularly vulnerable when the weather is persistently or abnormally adverse.

Against this adverse factor, which may be as unexpected in its incidence as it can be inopportune, our forecasting system is our prime defence. This defence may take two forms—the long-range forecast of general conditions weeks or months ahead, and the immediate forecast for the ensuing 6, 24 or 48 hours.

Reliable long-range forecasting that could have convinced Mr. Shinwell in the early autumn of 1946 that a winter of a degree of severity experienced only once in a century lay ahead would have been quite invaluable. But such forecasting is not yet within sight. Our knowledge of the larger dynamics of the atmosphere and of the factors which disturb it from year to year to give drought or flood, genial or extreme conditions, is quite inadequate to the task. The need here is clearly for fundamental research, a need fully recognised in authoritative quarters, e.g. by the Meteorological Committee of the Royal Society and the Meteorological Office. Research itself is slow, and the development and testing of forecasting techniques based on it must take time. No immediate aid in our present difficulties can therefore be looked for in this direction.

We turn, therefore, to our second line of defence—day-to-day forecasting. Can this be made to contribute more effectively to the daily conduct of our national business? Can it help agriculture, industry and transport to avoid or minimise the hazards that adverse weather periodically imposes on them? This article is written in the belief that it can, and to suggest a simple but radical change in our forecasting machinery that would lead to far more effective use being made of weather forecasts in practical affairs.

The suggestion that is here offered is based upon wartime experience which the writer shares with many of his readers, namely that while the R.A.F. forecasts of weather conditions over the target areas for long-distance bombing missions were always somewhat speculative and sometimes fully earned the scathing epithets which a distinguished Air-Vice-Marshal was on occasion heard to apply to them, the meteorological officers' forecasts of conditions at base were of a very high order of accuracy and reliability and earned just as fully the confidence which air-crews came to place in them. The lesson to be drawn from this contrast is two-fold. First, it is to be noted that forecasts of conditions at base issued to homing aircraft were prepared for a specific purpose by officers who understood very clearly how that forecast would be used and what depended upon it. Secondly, it is important to realise that while those forecasts were based upon the general analysis made by the Central Forecasting Branch, they were in fact framed by men on the spot with full regard to the known local conditions.

The introduction of those two principles into our national forecasting machinery would have far-reaching and beneficial consequences. This implies the issue of a regional forecast from a regional office by a forecaster who is well acquainted with all the topographical and other peculiarities of his locality, and equally who knows intimately what is going on in the region and how a forecast can best be framed to be most helpful to its inhabitants. This does not in any sense imply any criticism of the work done at the Central Forecasting Branch. Those who read Dr. J. F. Kirkaldy's article in the September 1946 issue of DISCOVERY (Vol. 7, pp. 262-9) will not need to be reminded of the elaborate organisation that is necessary to collect weather information from half a hemisphere and from sea level to 50,000 feet up and deliver it in code form to a single forecasting room, to realise that the basic analysis that must precede any worthwhile forecast can only be made in the Central Office. The function of regional officers would not be to make their own analyses of the general situation but to interpret the information supplied by the Central Office in terms of local conditions and practical needs. If the general analysis reveals the approach of a rain belt, the mention of this in the national forecast passes unheeded by the townsman, though not, of course, by the farmer. But even the townsman will begin to take note if he is told that rain in his

town is to be expected between 4 and 5 o'clock. Local forecasts can be made much more definite than national forecasts, and most so when they supply answers to specific questions. The national forecast reports "risk of fog on low ground or near large towns". The local meteorological officer can assess the risk of fog having serious consequences for transportation in relation to the towns in his area, and, if he decides the risk is real, can indicate fairly precisely the localities where thick fog may be expected. In the same way he can interpret frost risk in terms of local orchards or market gardens and issue forecasts that are related to the agricultural work actually going on in the area, giving shepherds warning of dangerous snowfalls and helping farmers at harvest time to have their men and machines at work at the first and the last possible moment. Changes of wind direction can reverse the drift of industrial smoke across large towns, and on winter days with low cloud may lead to sudden changes in the load at electric power stations, and a change of temperature associated with a change of air mass may have an immediate reflection in changed demand at the gas works. Warning in such cases is clearly valuable, and adequate meteorological advice might assist many a city engineer in the north to know whether to clear his streets of snow or to let it lie.

Agriculture and horticulture, industry, public utility and transportation undertakings, all have much to gain from such a regionalised meteorological service.* So have citizens and housewives who have scant respect or use for the service they receive at present. To institute such a service some twenty or even two dozen local branches of the Meteorological Office would need to be established—a small thing in comparison with the war-time establishment of meteorological stations in this country. Half a dozen of these would be earmarked particularly to provide rural service, and this would probably be most effective if they were set up in connexion with established agricultural colleges. The remainder would serve the principal urban areas—and it is suggested that all cities of half a million people, or groups of towns with a similar aggregate population, require such service. Our major health resorts will sooner or later realise that it is commercially worth while to engage their own forecasters to interpret information supplied by the Meteorological Office in terms of their special requirements. Such a forecaster might not be able to name a firm date for the next summer season's carnival, but he should at least be able to prevent the audience at the open-air theatre from getting soaked to the skin.

Many hard things are said about our British climate, but on the whole it is one of our valuable national resources, permitting agricultural, constructional and other outdoor activity through the year, imposing minimal difficulties upon our systems of transportation, and requiring a smaller expenditure of our fuel and power resources to keep ourselves warm in winter than in any other comparably industrialised country except Japan. But to make the best use of this resource requires a forecasting service that is designed to that end. It must enable us to take advantage of fair weather and avoid being caught out by foul, and to do this it must issue local forecasts based upon the fullest possible analysis of the synoptic situation at the Central Office, but framed realistically by local men in the light of local knowledge and practical needs.

* The institution of a commercial forecasting service to Birmingham industry was headline news in the *Daily Mirror* of January 6, 1948.

SCIENCE IS UNESCO'S STRONG POINT—*Contd. from page 42.*

human excellence, of spontaneous internationalism which transcends frontiers, of common purpose which does not await the behests of governments. They would find subjects which, on their own merits (and not as an obligement to Unesco), would appeal to authors, film-directors and radio-producers, who already command their own audiences and who need only inspiration and facilities. Unesco's dividend (and it would be a substantial one) would be the acknowledgment of its co-operation or its imprimatur on the venture. Unesco cannot afford to produce feature films, but it can get the feature-film industry to produce them if the ideas are good box-office. Unesco cannot afford to have a world-wide radio network, but it can, with the right sort of programme, 'gate-crash' the existing networks with their ready-made audiences. Unesco cannot compete with the newspapers or the glossy magazines, but it can get space for the kind of stories (yes, fiction if need be) which those would carry on international themes. What we were financing to the tune of half-a-million dollars was brains and imagination, married to the sound intentions and high objects of Unesco.

The same kind of test was applied to the social implications of science. Scientists must themselves realise the social implications but so—even more so—must the public. In addition, therefore, to the fellowships which Unesco is going to award for the academic study of social implications (with the object of it eventually becoming a university subject) it was agreed that Unesco should ask its member nations to initiate debates and discussions on effects of a scientific discovery (to be suggested by Unesco) on the social organism. These discussions, with popular as well as group-appeal, should be on common ground so that Unesco could secure a world-pattern of 'implications'.

There is no doubt that what emerged from Mexico City, despite handicaps, was a worthwhile and workmanlike programme answering the tests: (1) Is it of practical assistance? (£25,000,000 raised by voluntary subscription in America, above and beyond the Unesco budget, is to be spent on rehabilitation of war-devastated schools, universities, libraries, museums, etc.) (2) Will it get across frontiers? (3) Is it sharing practical experience and not just blah? (4) Will it capture the popular imagination?

After all, as Dr. Monge tried to tell us and we learned by salutary experience, it takes a long time to get acclimatised to rarified heights—intellectual as well as physical—and Unesco will do its best work at ordinary levels.

Transplanting Mammals' Eggs

NEW TECHNIQUES THAT MAY REVOLUTIONISE ANIMAL BREEDING

CHAPMAN PINCHER, B.Sc.

JUDGED by the critical yardstick of consistent milk production, top-grade British dairy cattle are the best in the world but the great majority of our milking cows are of poor quality. If our high-performance stock could be introduced into commercial dairy herds on a really big scale the country's milk production might be trebled without any corresponding increase in the consumption of feeding-stuffs. Big yielders eat little more food than poor cows: they simply use their rations more efficiently. But first-class cows are too few and their natural rate of reproduction is too slow for any rapid replacement of the poor-quality beasts to be made by established farming methods.

By putting bulls of good milking strain at the service of many farmers artificial insemination is helping to upgrade commercial cattle, but its effects will always be limited so long as the females remain basically of poor stock. Their slow reproduction rate—few cows produce more than ten calves, half of which may be bulls—would seem to be an insuperable obstacle to any plan for providing big numbers of top-grade milkers to dairy farmers.

But a trend of research now proceeding rapidly may overcome it. *It may soon be possible, and perhaps practicable, for any high-quality dairy cow to provide two hundred high-quality calves every year.* The only way to judge the feasibility of this seemingly fantastic scheme is to consider the progress already made in the research referred to.

First, a few words must be devoted to summarising the reproductive processes of the cow. The cow comes into heat about every 21 days. Just after the end of heat ovulation occurs, that is, one of the ovaries sheds an egg. This egg—just big enough to be seen with the naked eye—makes its way into the corresponding Fallopian tube (see Fig. 1), where, if the cow is mated at this time, it meets the sperms of the bull. One sperm succeeds in fertilising the egg which then slowly descends to the uterus where it becomes attached to the wall. During pregnancy which lasts nine months no further eggs are produced. Both heat and egg-production are resumed shortly after calving.

Ovulation is largely controlled by the pituitary gland—a small knob attached to the underside of the brain. The front part of this gland secretes into the bloodstream hormones called gonadotrophins which stimulate the ovaries to ovulate.

A supply of these hormones for experimental purposes can be obtained from the pituitary glands of slaughtered animals or from the blood serum of pregnant mares.

This description of the cow's reproductive processes applies broadly to nearly all mammals except for the fact that in many of them several eggs instead of one are set free at each ovulation. The rabbit, for instance, which because of its small size and rapid rate of breeding is widely used in research on mammalian reproduction, may normally shed up to 15 eggs at a time.

Since the release of gonadotrophins from the pituitary into the blood is the stimulus which triggers the shedding of a certain number of eggs from the ovaries, the artificial injection of an extra amount of gonadotrophin might be expected to increase this number. This has been found to be the case.

A laboratory technique for the artificial production of abnormally high numbers of rabbit eggs has been devised by Dr. Gregory Pincus and his associates at the Worcester Foundation for Experimental Biology at Massachusetts. He used a strain of rabbits which normally set free about nine ova at each ovulation. When he injected young does with an extract of sheep pituitary gland the average number of eggs shed increased to 28·5, the actual numbers ranging from 11 to 80. (Each doe was given six priming injections of the gonadotrophin subcutaneously at 12-hour intervals. Then 8–12 hours after the last priming dose ovulation was induced by an intravenous injection.)

There seems to have been nothing abnormal about these 'superovulated' eggs. When adult rabbits which had been given the treatment were mated, it was found that the eggs were fertilised quite normally and that their subsequent development was quite normal. One doe treated in this way was found to have 36 living embryos inside it. Of course, not all these embryos would have developed. It seems certain from other evidence that either the entire litter would have died and been absorbed in the womb, or that most would have perished leaving a litter of about normal size. Rogers Brambell has shown in his study of wild rabbits in Caernarvonshire that about 60% of all litters conceived are lost owing to the death and absorption of all the embryos, and that in litters which survive to birth there is a loss of about 10% of the ova shed.

There is, however, a practicable way of ensuring the survival and subsequent birth of a high proportion of the 36 or so eggs which may get fertilised in a rabbit subjected to superovulation treatment. The technique is again due to the experimental workers of the Pincus school, and especially to Dr. M. C. Chang.

Fertilised ova whether normal or superovulated can be obtained undamaged from the Fallopian tubes of pregnant

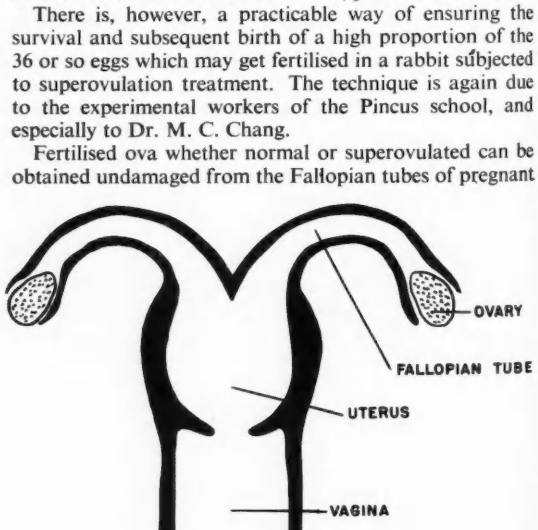


FIG. 1.—Reproductive organs of a cow in section.

does. (This involves surgery.) Dr. Chang succeeded in storing fertile eggs so obtained (from rabbits which had been given the superovulation treatment and then mated) in rabbit serum at low temperatures. He found that if they were stored at 10° C. for 24 hours, 82·2% of the rabbit eggs remained alive. When cultured at 37° C. after storage they started dividing in the normal way. He then proved their vitality in the most definite way possible by transplanting stored eggs into virgin does and obtaining living young.

The virgin does were first injected with a gonadotrophin solution to get the reproductive system into a receptive condition. Twenty-four hours later 4–15 ova were then transplanted into the Fallopian tubes of each rabbit. The method of doing this was worked out by Pincus. By simple surgery the ovaries and Fallopian tubes are exposed. The fertile eggs to be transplanted are then carefully drawn into a fine syringe with the minimum amount of fluid. The syringe is inserted into the funnel of each Fallopian tube in turn and the eggs gently expelled.

In Chang's experiments four does which had received eggs previously stored at 10° C. for 80–101 hours gave birth to litters of one to four young. Four litters of two to seven young were obtained from eight does after transplantation in them of eggs stored at 5° C. for 48–80 hours. After transplantation of eggs stored at 0° C. for 78–102 hours, four litters of one to two young each were delivered. One litter of young was obtained from two does who had received eggs stored at 15° C. for 72 and 96 hours.

All the young were healthy and normal. Genetically they were true to the does which provided the eggs from which they developed and to the bucks which had fertilised them.

From this mass of experimental data it is clear that a laboratory method of rearing abnormally high numbers of rabbits from females of any desired genetical strain has been established.

What grounds are there for believing that a technique for the rapid breeding of high-quality cattle by this process of *ovular transplantation* could ever be developed to the point of practical use?

The requirements are:

(1) A safe and simple method of inducing cows to "superovulate".

(2) A technique for obtaining the eggs after fertilisation quickly and without injury to them or to the female producing them.

(3) Means of storing the eggs long enough for their transport to farms.

(4) A technique for implanting them into low-quality cows which would act as foster mothers. ('Low quality' refers to their inherited capacity for milk production. As regards general health and ability to produce sturdy calves, the cows chosen to act as foster mothers would, of course, be good specimens.)

The practicability of inducing 'superovulation' regularly in cows has already been established. Folley and Malpress at the National Institute for Dairying Research, Shinfield, have shown that big doses of pregnant mare serum given late in the heat-cycle cause 'superovulation'. They used in their experiments 151 fattening heifers and 70 cows of various breeds destined for slaughter, with 10 untreated heifers serving as controls. The injections were given subcutaneously in the shoulder. The ovaries and Fallopian tubes of each beast were later examined at autopsy. According to the published report of the experiments 16 eggs was the biggest number recovered from any one beast. But Dr. Folley told me that cows have been induced to shed up to 57 eggs at a time in further experiments with pregnant mare serum at Shinfield.

The same workers studied the possible long-term effects of pregnant mare serum gonadotrophin on cows. Examination of beasts killed at intervals up to a year after injection showed that in general the ovaries returned to normal with no permanent impairment of breeding power.

Folley believes it would not be harmful to obtain up to 200 eggs a year from a healthy cow by the gonadotrophin injection method. There would be no danger of prematurely exhausting the cow's supply of eggs by this process. The average cow has a total stock of some 75,000 eggs in its ovaries. Normally less than ½% of them are ever used: the rest, containing genes which may have taken years of patient breeding to assemble, are wasted.

The next step is to devise a method of obtaining the superovulated eggs after they have been fertilised which does not involve killing the cow. This, too, has already been done.

In work not yet published, Professor W. E. Peterson of Minnesota has recovered one dividing egg by irrigating the uterus of a cow with a sterile saline solution some hours after 'superovulation' had been induced. But in order to obtain a reasonable proportion of the eggs set free after gonadotrophin stimulation it is likely that a new technique will have to be devised.

The problem might be overcome by a single surgical operation early in the life of each cow to be used as an egg donor. It should be possible, by cutting each Fallopian tube and leading the cut end to an incision in the abdominal wall, to establish two permanent openings from which the eggs would be extruded instead of passing into the uterus. Such an operation should be neither difficult nor dangerous.

Fistulas (artificial openings) permanently linking the stomach and other parts of the alimentary canal with the exterior have often been made in experiments with cattle. The animals concerned have thrived and seemed little inconvenienced by the treatment. There seems to be no reason why the production of Fallopian tube fistulas in breeding cows could not become as acceptable in farming practice as castration or docking.

To develop means of storing the eggs for a few hours and transplanting them to scrub cattle may prove more difficult. But Professor Peterson was able to introduce what he believed to be a still-living cow egg into the womb of another cow and there are some indications that it is developing there.

It is clear then that work towards adapting the techniques of ovular transplantation to cattle is well advanced in the United States, and I am informed that British research establishments are planning similar projects.

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Oil from Coal

HOW GERMANY SYNTHESISED PETROL FOR WAR

A. D. CUMMINGS, M.Sc., F.Inst.Fuel

BOTH in peace and in war petrol and oil are needed for transport. Since nothing can be much cheaper than oil from a hole in the ground, natural petroleum is from the point of view of price the only sensible source of these necessities in normal times. But when a country that is without natural oil within its borders is faced with the prospect of war the question of making certain of her supplies of oil leads to different expedients according to the country's position, resources and mental state.

During the 1930's Germany was planning to go to war, and this country was preparing to resist her. Both countries are practically without natural oil and in both countries the possibility of making oil from coal on a large scale was considered as a war-time measure. The cases were, however, very different. Britain could rely with some degree of certainty on sea-borne oil (protected by the Navy) to see her through in the still uncertain event of war. The question of oil from coal *versus* tankers and storage was weighed and considered, and the decision was against any extension by government assistance of our small synthetic oil industry. Some people think that this was unwise, and contend that we should at least have carried the experimental work being done by the Fuel Research Board on these processes to a bigger scale. (As events have turned out the Germans have done this for us.) Germany's case was this: war was a practical certainty, she could not count on any sea-borne oil, and the oil-fields she could draw supplies from overland were in Poland, Rumania and, as long as friendly relations could be maintained, Russia. The first two of these countries were likely to fall into German hands quickly, but were not likely to yield enough oil. Agreement with Russia was not reached until 1939 and the Russian supplies of oil were probably left out of account, at any rate at the beginning. Of necessity, the Germans had to put considerable reliance on these oil-from-coal processes, whose feasibility had only recently been proved and which were known to be expensive and technically difficult. A totalitarian government has the advantage of controlling absolutely the whole resources of a country and the lives of its people. By any reasonable peace-time economics there is nothing to be said for a process that makes oil at home at two or three times the price at which it can be imported. If, however, it is the rulers' intention to turn the country into a fortress from which to fight the world, ordinary economic considerations go by the board, and the only questions arising are: Have we the technical skill, the raw materials and the man-power required?

All these Germany had and, the necessity being judged great enough, the decision was taken well before the war to put a large part of their productive skill into building oil-plants based on coal and lignite as the raw materials.

There were two processes available, twelve large plants of one kind were built and these provided about half the liquid fuel needed, eight of the other type provided about another ten per cent. The first was given the higher priority because it made better aviation spirit, the other was more useful as a source of diesel oil for submarines and heavy vehicles. The risk to such plants from air attack was considerable, and indeed all these plants were heavily bombed; they were destroyed or badly damaged, repaired and smashed again. Whatever one's views about the ethics of air bombing, there can be no question but that these plants were legitimate targets and their destruction was bound to shorten the war. One can only wonder why, in view of their vital importance to the Germans, it was left until as late as 1944 before most of them were finally put out of action. (It has recently been disclosed that in June 1944 the Supply Minister Speer was reporting to Hitler that sources of aviation spirit were 90% destroyed.)

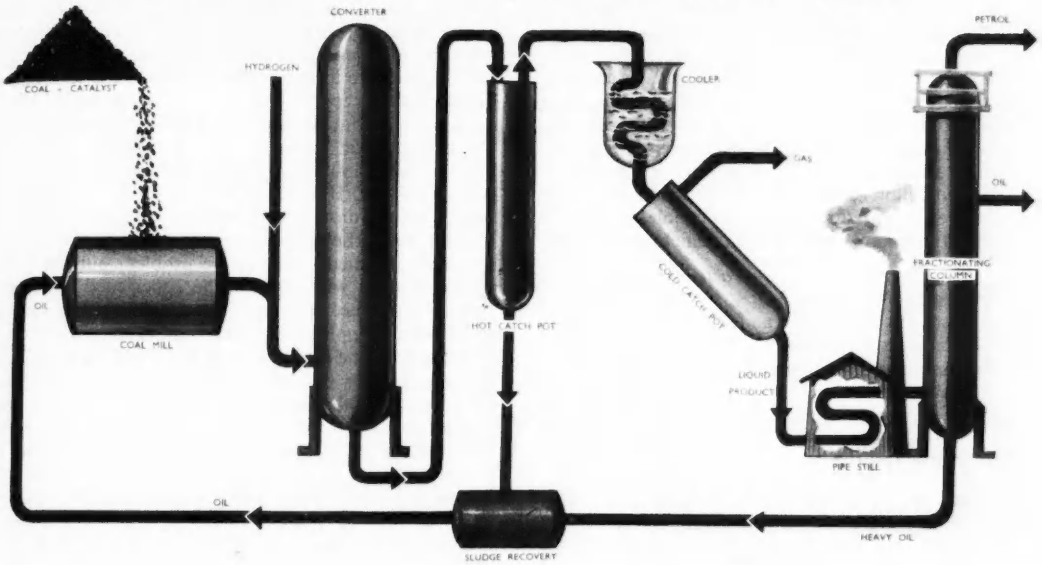
As now used, these processes are not an economically successful solution to the problem of providing oil in those countries that have no natural oil; the petrol obtained from them still costs at least twice as much as the natural oil, which has been refined and transported to its destination. Using hard coal it takes nearly 5 tons of coal to make a ton of petrol; using brown coal it takes 17 tons of raw coal from the mine; moreover, the capital cost of oil-from-coal plants is enormous. Only a country whose need was desperate would contemplate using them in the present circumstances. The processes have no future until natural oil resources dwindle even more rapidly than they are doing at present.

Two Different Processes

Fuels for carburettor engines are fairly simple hydrocarbons with about six or eight carbon atoms in their molecules, the proportion of hydrogen to carbon by weight being about 1 to 6. Fuels for diesel engines are of the same type with about twice as many carbon atoms and the same proportion of hydrogen to carbon.

Coal, the raw material for making oil, is an aggregate of complex molecules each containing perhaps 100 carbon atoms, and the proportion of hydrogen to carbon is about 1 to 15 by weight. The problem of turning coal into oil is to break down the complicated molecules in coal and persuade the 'unsaturated' carbon atoms to take on more hydrogen. There are other elements in coal which take up some of the hydrogen and otherwise complicate matters. The job of getting in more hydrogen can be tackled in at least two ways; one is to push hydrogen into the coal molecule to loosen up the complex structure without smashing down the carbon chains too far; the other is to convert the coal to carbon monoxide by regulated combustion and then to substitute hydrogen for oxygen, at the same time building up the single carbon atoms into chains of the right length. You cannot gasify coal direct with hydrogen and get chain compounds; the process tends to go too far and give the gas methane, in the molecule of which single carbon atoms are fully saturated with hydrogen. The first process, the regulated breaking down of coal molecules, is called *hydrogenation* and has been developed on a large scale in

OIL FROM COAL BY THE HYDROGENATION PROCESS



Britain. The second, building up from single carbon atoms, is usually called the *Fischer-Tropsch Synthesis*.

Hydrogenation of coal was discovered by Bergius about 1916 and reached commercial success about ten years later. In 1931 there was an arrangement made between the I.G. Farbenindustrie of Germany, the Standard Oil Company of America, the Royal Dutch Shell Group and the Imperial Chemical Industries of this country (all of whom were interested in the process) by which all their information and patents about the method were pooled. The Billingham plant of I.C.I. was producing 150,000 tons of petrol (40,000 tons from creosote, 10,000 from tar, and the remainder from raw coal) a year after they had developed it from a laboratory scale to a first-rate technical success, but it only made a profit by virtue of the import duty on imported petrol. During the war creosote completely replaced coal as the raw material for Billingham, with the exception of the coke used for making hydrogen. At Heysham another hydrogenation plant for making petrol has been operated, by Trimpell Ltd., since 1941; the starting material here was gas oil, not coal, though large quantities of the latter were used in connexion with the preparation of hydrogen.

The Fischer-Tropsch process was discovered in 1925 and reached a commercial scale only in Germany and Japan, though a good deal of useful work has been done on it at Britain's Fuel Research Station. It is a little simpler in plant requirements than the other but the cost of the final products, which can be varied considerably, is about the same. There is great interest in this process in countries with big resources in natural gas or easily worked low-grade coals that can be turned into gas. There is a large plant building in America now to make 300,000 tons of petrol a year from natural gas. It is unlikely at present that suitable gas can be made cheaply enough in Britain to make it commercially possible, though the wide range of organic chemicals it can produce makes it desirable that it should be tried if not in Britain then at any rate within the empire. The first such project is to be based on the cheap coal of South Africa. The two processes will now be described in outline. (Much detailed information is given in the Allied Reports on German Industry, published by H.M. Stationery Office.)

Hydrogenation.—The raw material can be bituminous coal or lignite; coal tar and heavy oils have also been used, alone or with coal. There are two or sometimes three stages. In the first, coal is converted into a heavy oil; in this stage the hydrogen is added to a coal-plus-oil liquid. In the second, the oil made in the first stage is further treated, this time in vapour condition, with hydrogen. In the third, this product receives further treatment to improve its quality. In each of these steps the reaction is promoted by the use of a catalyst, i.e. a substance that helps to bring about the desired combination but remains unchanged itself. The steps, then, are:

(*a*) Coal + Mixing Oil + Hydrogen	⟶	Middle Oil + Unconverted Coal + Gas.
(*b*) Middle Oil + Hydrogen	⟶	Diesel Oil + Petrol + Gas.
(*c*) Diesel Oil + Hydrogen	⟶	Petrol of aviation quality, rich in anti-knock substances.

The coal is freed from mineral matter (ash) as far as possible and is ground to a fine powder, mixed with heavy oil made in the process to make a fluid that can be pumped and a small amount of tin oxalate or other catalyst added. This mixture and the hydrogen at a high pressure—300

atmospheres or in some cases 700 atmospheres—are first passed through heaters to raise the temperature to about 450° C., then through the converters where the hydrogen is combined. The product is delivered into a 'hot catch-pot' where the pressure is released, gas and sludge (uncombined coal and ash) are separated off and the oil is separated into petrol and mixing oil. The gas, on cooling, yields ammonia liquor and light hydrocarbons which have been used in a compressed state as 'bottled gas' for motor fuel. The remaining gas is hydrogen and methane; the latter is converted to hydrogen and the whole returned to the system. The quantities of the products are:

	Parts by weight
Petrol and Middle Oil	62
Oil lost with slime (used as fuel)	6
Gas (returned to process)	24
Liquid (water and ammonia)	9
Unconverted Coal	8
TOTAL	109
Hydrogen absorbed	9
Original Coal	100

Special problems arose in hydrogenating brown coal or lignite; this was used, in spite of the fact that it is not as suitable as hard coal, because it was cheap and easy to mine, and hard coal was wanted for other purposes. The grinding had to be done in an atmosphere of carbon dioxide to prevent the coal from catching fire, which it very readily does in a dry powdered condition. The reaction chambers easily became choked because it was not possible to separate the mineral matter from the coal, and this was of necessity carried through the system. In the hot reaction chambers it formed granular deposits (referred to as 'caviar' since it was in the form of small spheres) and these in time would block the converters entirely and were very difficult to remove. Owing to the higher oxygen content of lignite the amount of hydrogen wasted by combination to form water was greater than with hard coal. A better method of utilising brown coal (practised at some plants) is to carbonise it in special retorts making coke, tar and gas; the gas is used to heat the retorts, and the coke is used to make hydrogen with which the tar is then hydrogenated.

Fischer-Tropsch Process.—Because this process works at atmospheric or only slightly higher pressure and at lower temperatures, it is rather simpler and cheaper in initial cost of plant than hydrogenation, but lower pressures mean that bigger volumes of gas have to be handled and the plant as a whole occupies more ground-space for the same output of products. The reaction takes place with evolution of heat, and this must be dissipated or harmful results will follow; the means used by the Germans for doing this were cumbersome, and this led to the multiplication of small units, making control more difficult.

A mixture of carbon monoxide and hydrogen evolved from coke and steam is adjusted so that these gases are in the proportion of 1 to 2 by volume; the presence of small amounts of other gases not harmful to the catalyst do not make any difference. The gas is carefully purified from sulphur compounds (which poison the catalyst) and are passed through 'contact ovens'. These are metal boxes containing solid granular catalyst material held amongst finned tubes through which hot water circulates; these tubes are all connected to a steam drum outside the oven, and the pressure in this serves to control the temperature. The catalyst is cobalt and thorium oxide on kieselguhr, a natural siliceous earth and is a poor conductor of heat. The way it is packed in the contact oven is to ensure that none of the granules are more than about $\frac{1}{4}$ inch from a cooling surface. If the catalyst heats up to something over 200° C. carbon dioxide and methane are formed instead of liquid hydrocarbons. It is this heat dissipation that has presented a difficult engineering problem but the present clumsy devices will probably be superseded when more experience has been gained. (The problem has in fact been solved by the application of the fluid catalyst technique as developed for the catalytic cracking of petroleum.)

The gases after passage through the ovens contain about a pound per 100 cubic feet of hydrocarbons. These are washed out with water by passing through open towers containing some packing over which water sprays. The final gas ('tail gas') after absorption of light hydrocarbons in charcoal is used for heating. By varying the conditions of pressure, temperature and gas-re-circulation the range of products can be varied, but most of the German plants worked to produce the following:

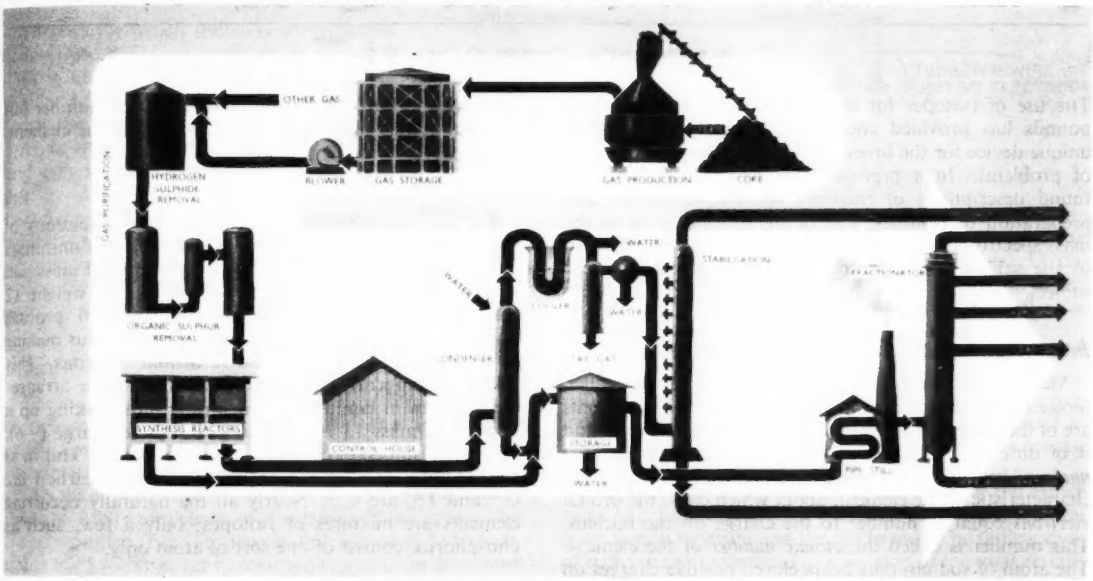
	At atmospheric pressure, cobalt catalyst	*At higher pressure, iron catalyst*
	%	%
Low boiling-point hydrocarbons, used as bottled gas.	14	10
Motor Spirit, boiling-point range 30–165° C.	47	26
Diesel Oil, boiling-point range 165–230° C.	17	24
Heavy Fuel Oil, boiling-point range 230–320° C.	11	13
Soft Wax, boiling-point range 320–460° C.	8	17
Hard Wax, boiling-point range above 460° C.	3	10
	100	100

The waxes were a valuable product from which were made detergents, plasticisers, insulating materials, soap, and cooking fats of rather dubious nutritional value.

As will be seen, the medium pressure method (10–20 atmospheres) gives more diesel oil, and since the motor spirit from this process is of poor quality, considered from the point of view of its use as aviation spirit, and the diesel oil is very good, this was the preferred method. The substitution of the cheaper and more easily available iron catalyst was never complete, but cobalt was very short at the end of the war.

The hydrogen for hydrogenation and the synthesis gas for Fischer-Tropsch were obtained by similar methods, the basis in all cases being the 'water-gas reaction' in which carbon reacts with steam to make equal volumes

PRODUCTION OF OIL BY FISCHER-TROPSCH PROCESS



of hydrogen and carbon monoxide. The raw material could be hard coke (i.e. the kind made from bituminous coal in coke ovens), brown coal or brown-coal coke. If hard coke was used, it was gasified by blowing through it air and steam alternately, the air to raise the temperature and the steam to make the gas. This is a well-established process used in gas works all over the world. The resulting gas, if hydrogen is wanted, is passed with more steam over a catalyst, when the carbon monoxide reacts to form carbon dioxide and more hydrogen. All carbon oxides are then removed by washing, and pure hydrogen is left.

If brown coal was the starting point, there were several methods in use. In the Pintsch-Hillebrand system raw brown coal was dried and compressed into briquettes. These were passed through a vertical fire-clay retort or tube against a stream of very hot water-gas mixed with steam. The gas stream leaving the top of the retort was cleaned and divided in two, part went to the next stage and part went through a heater and back to the base of the retort.

The Wintershall-Schmalfeldt system was very similar in idea, but in this the raw brown coal with 50% of water was powdered and gasified with a mixture of water-gas and steam in tall brick towers. As before, the resulting gas was split after cleaning, part going to the next stage and part back to the reaction towers. All the apparatus is on a huge scale, and there does not seem to be any advantage over the first method.

In the Winkler system, brown-coal coke made in special retorts is crushed and fed into a large open generator where it is gasified with steam mixed with oxygen (from liquid air). The fuel bed occupies a few feet at the base of a tall tower and is held in a 'boiling' condition by the steam-oxygen blast. The gas mixture from all these plants is very similar, as can be seen from the table below, and removal of carbon dioxide from it leaves a synthesis gas that is nearly correct for the Fischer-Tropsch process.

	Pintsch	*Schmalfeldt*	*Winkler*
	%	%	%
Carbon dioxide	14	10	23
Carbon monoxide	28	28	30
Hydrogen	56	56	44
Methane	1	3	1
Nitrogen	1	3	2
	100	100	100

All the plants working these processes in Germany are now in ruins, and there is little likelihood of their being rebuilt in the present circumstances. The position about hydrogenation of coal in Britain has already been quoted. According to a recent paper on the Fischer-Tropsch process there is not much can be done with it unless the cost of synthesis gas can be reduced, which means it can only be usefully employed in countries with natural gas or low-grade coal that can be won by open mining or gasified underground without mining.

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Labelled Atoms

(THE USE OF ISOTOPES IN BIOLOGY AND MEDICINE)

RAYMOND GLASCOCK, B.Sc.

THE use of isotopes for labelling chosen atoms in compounds has provided chemists and biochemists with a unique device for the investigation of a very large number of problems. In a previous DISCOVERY article* will be found descriptions of methods for the separation and preparation of isotopes, and of instruments such as the mass spectrometer. The reader is therefore only reminded of the salient points in the background to the present subject.

Atoms and their Chemical Behaviour

Matter consists ultimately of small particles called molecules which are combinations of atoms. If the atoms are of the same sort the substance is called an *element*, and if of different sorts a *compound*. An atom consists of a *nucleus*, bearing a definite number of positive charges characteristic of the element, about which circle the orbital *electrons* equal in number to the charge on the nucleus. This number is called the *atomic number* of the element. The atom of sodium thus bears eleven positive charges on its nucleus and has eleven electrons in the surrounding shells. As the electrons are negatively charged, the whole atom is neutral. If we magnified the atom so that the nucleus were the size of a football the outermost electrons of a light atom such as sodium would be about six miles away. The major portion of the atom is empty space.

Atoms are, of course, very light, and the unit of weight is that of the hydrogen atom. This is 1874 times the weight of an electron, and hence it is obvious that most of the mass of an atom resides in the nucleus. The *atomic weight* of sodium is 23, which means in effect, that the nucleus is 23 times as heavy as the hydrogen nucleus or *proton*.

The chemical behaviour of atoms is determined solely by the electrons in the shells or orbits—that is to say, it is determined by the outside of the atom. The *number* of electrons is determined by the charge on the nucleus—that is the atomic number. Thus an electrically neutral particle with six positive charges on the nucleus and six electrons is an atom of *carbon* and it will show all the properties of carbon—it will, for example, combine with two molecules of oxygen to give carbon dioxide which will in its turn react with sodium hydroxide to give sodium carbonate and water.

Isotopes

It is only the atomic number that determines the chemical nature of an atom, and it is possible for two (or more) nuclei to have different weights but the same charge or atomic number. If this occurs then we will have, when they are complete with their attendant electrons, two atoms of the same element but with different atomic weights. They will be identical in all respects except those in which mass is important. Atoms of the same atomic number but different atomic weights are called *isotopes* of the element.

* 'Isotopes' by B. A. Lister, DISCOVERY, 1946, Vol. 7, pp. 15–19 and pp. 40–46.

Stable Isotopes

The nucleus is thought to consist of combinations of two sorts of fundamental particles: the *proton* of unit mass and unit positive charge and the *neutron* of unit mass and zero charge. An atom of carbon of atomic weight 12 consists therefore of a nucleus comprising 6 protons (thus giving a charge of +6) and 6 neutrons (thus making up a total mass of 12) and the 12 orbital electrons. This nuclear arrangement is stable. Another stable arrangement differs in containing 7 neutrons thus making up a nucleus of mass 13 but still with the same charge (+6). This is an isotope of carbon of atomic weight 13 known as C^{13}. About 99% of the atoms of ordinary carbon are C^{12} and 1% are C^{13}. Nearly all the naturally occurring elements are mixtures of isotopes; only a few, such as phosphorus, consist of one sort of atom only.

Radioactive Isotopes

All the elements whose atomic number is greater than that of bismuth (83) are radioactive; that is to say from time to time the nucleus of an atom disintegrates emitting a particle (electron, positron, proton or α-particle) the residue thereby changing, usually, into a nucleus of another element. This occurs because the arrangement of primary particles in the nucleus is unstable. Radioactivity has been known for over half a century and until 1934 only the naturally occurring radioactive elements—radium, uranium, thorium, etc.—were known. In 1934, however, artificial radioactivity was discovered, when means were found of producing unstable nuclei of the lighter elements. Now artificial radioactive isotopes of nearly all the elements are known. They are usually made with the cyclotron whereby stable nuclei are bombarded with high-speed particles (protons, deuterons, α-particles, etc.) causing a change in the nucleus to an unstable configuration. Though the cyclotron has been most used in the past it is likely that the uranium pile will be the principal source of the future. As an example of a transmutation carried out with the cyclotron, the neutron bombardment of chlorine may be cited. The stable chlorine nucleus becomes an unstable nucleus of sulphur with a mass of 35. Ordinary sulphur consists of S^{32}, and S^{35} is available as a tracer.

Radioactive substances decay with the emission of several sorts of radiations. *α-rays*, confined almost exclusively to the heavy, naturally-occurring radio-elements, consist of charged helium nuclei. *β-rays* are streams of electrons. These may vary in energy; C^{14}, for example, emits 'soft' or low energy β-rays while P^{32} emits the 'harder' radiation of higher energy electrons. *Positrons* are particles of the same mass as electrons but *positively* charged. They are emitted by a number of the tracer elements, C^{11} for example. *γ-radiation*, often emitted

simultaneously with one or more of the other radiations is similar in nature to X-rays.

The rate at which the radioactive atoms disintegrate is the other important variable. This is usually reported as the *half-life* of the element, which is the time taken for half the atoms in any sample to disintegrate. This time is a constant for each element and cannot be altered by any known means but it varies among the elements from microseconds to thousands of years. The half-life of C^{11}, for example, is 20 minutes. That means that the radioactivity of a sample will have declined to half in the first 20 minutes, to a quarter in the next 20 minutes, to an eighth in the next and so on.

Instruments

The instruments used for the detection and estimation of isotopes are the *mass spectrometer* and the *Geiger-Müller counter** which deal with stable and radioactive isotopes respectively.

The mass spectrometer determines the *relative abundance* of each constituent in a mixture of isotopes. The Geiger counter (Fig. 1), detects and measures radiations and is used with respect to *radioactivity* much as a balance is used with respect to *weight*. In ordinary chemical work an attempt is made to account for the weights of various substances used during an experiment: so many grams taken, so many grams left unreacted, so many grams of product and so many grams lost as by-products. In tracer chemistry with radio-elements an attempt is made to account for all the radioactivity. The radioactive substance used at the start of the experiment is assayed with the counter—instead of being weighed—and its activity reported as so many *counts per minute*. The unreacted substance, the products, the losses and so on can also be reported in terms of counts per minute. Only in one respect does the analogy with *weight* break down and that is in the case of the short-lived elements. With C^{11}, for example, the half-life is only 20 minutes and there will be a considerable loss of total activity during the experiment which must be taken into account when calculating results. For most experiments about two million counts per minute is a suitable dose.

Tracer Chemistry

The first use of a radioactive isotope as a tracer was reported by Hevesy in 1923. The naturally-occurring radio-element *thorium* decays radioactively with the formation of a gas called *thorium emanation* which is itself a radioactive element; it decays to *thorium B* which is a solid deposit. Thorium B is a radioactive isotope of lead.

Hevesy charged a piece of platinum foil to a potential of 100 volts and immersed it in thorium emanation. Thorium B collected on the surface of the foil and was subsequently washed off with nitric acid. The *weight* of the isotope was exceedingly small, of course, and consequently some lead nitrate was added as a *carrier*. The use of an inactive isotope as a carrier is very common in tracer chemistry: isotopes are seldom used carrier-free. In this case, thorium B and lead being identical chemically it was known that wherever the lead went, the thorium B must follow, giving notice of its whereabouts by its radiations.

*See 'The Geiger-Müller Counter', DISCOVERY, 1947, Vol. 8, pp. 130-2.

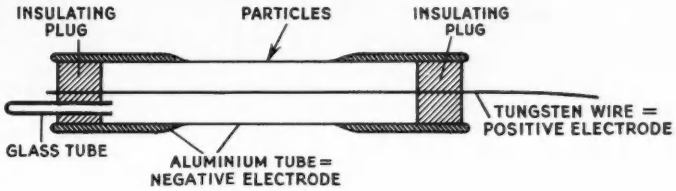


FIG. 1.—Diagram showing design of a typical Geiger-Müller counter.

Hevesy then allowed seedlings of the broad bean to stand in a dilute solution of radioactive lead nitrate. After some time the plants were removed, washed thoroughly and examined for radioactivity. Hevesy used an electroscope which is a tolerable but much less accurate instrument than the modern Geiger counter.

The total radioactivity of the solution before the experiment had been determined, and the separate parts of the plant were now burnt and the ash tested. The radioactivity of each part was expressed as a fraction of the total activity before the experiment; and as the plant could not distinguish between radioactive and inactive lead the value thus obtained was the fraction of the total lead absorbed by the organ. His results were as follows:

Part of plant	*Percentage of total lead originally in solution and now contained in ash*
Root	13·000
Fruit	0·100
Stem	0·050
Leaves	0·013

Hevesy thus demonstrated that the root absorbs lead but, during the time occupied by the experiment, does not transmit appreciable quantities to other organs.

Hevesy's experiments were the first of a large number in which radioactive isotopes were used to label specific atoms or groupings in molecules. Another technique, developed principally by Schoenheimer and Rittenberg in America, uses the stable isotopes as labels.

The stable isotopes have the advantage for tracer experiments in that no change takes place in the isotope however long the experiment may be prolonged. Experiments with radio-carbon C^{11} of half-life 20 minutes must be done very quickly if the radioactivity is not to have declined to too low a value for significant results: 10 half-lives, in this case 3 to 4 hours, is about the limit. Experiments with the stable isotope C^{13}, however, may last as long as the investigator likes. Stable isotopes may also be used on human subjects without danger of ill effects from radiations. On the other hand methods for the detection and estimation of stable isotopes are often less sensitive than those used for the radio-elements.

An example of the use of a stable isotope is given by the investigations carried out by Rittenberg and Waelsch

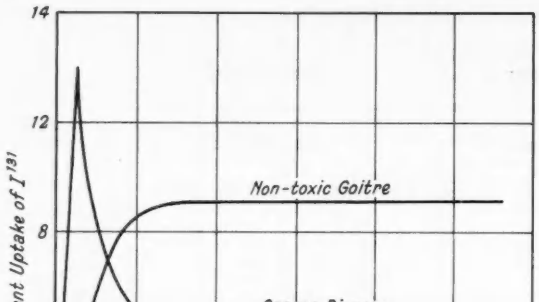


FIG. 2.—Curves obtained by plotting radio-iodine uptake against time, in three cases of thyroid disorders and in a normal individual. The non-toxic goitre and normal control follow curves of similar shape indicating that the thyroid tissue in the non-toxic goitre is functioning normally but that there is too much of it; it has overdeveloped in trying to cope with a meagre supply of iodine.
The case of Graves Disease gives a curve of an entirely different shape indicating a rapid uptake and a rapid loss of iodine, while the case of myxoedema is characterised by an almost total inability to absorb iodine.

(1940) on the origin of the carbon in urea synthesised by liver tissue. Proteins, which contain combined nitrogen, are decomposed in the liver. Ammonia, which is among the first products of this decomposition, is converted by the body into the less toxic substance urea, $CO(NH_2)_2$, which is excreted in the urine. Rittenberg and Waelsch set out to find the origin of the carbon in the urea. It was suspected to be carbon dioxide (a product of the respiration of all tissues) either free or combined as bicarbonate. Sodium bicarbonate was therefore prepared from C^{13}-enriched carbon dioxide—that is to say, when analysed in the mass spectrometer the relative abundance of the heavy isotope was greater by a known amount than that of ordinary carbon dioxide.

The bicarbonate was dissolved in a suitable nutrient solution containing also ammonium chloride, glucose and ornithine (an amino acid thought to be essential to the chemical reactions involved in the conversion of ammonia and carbon dioxide to urea).

Slices of liver were shaken with this solution for two hours at blood temperature. At the end of this time the liquid portion was treated to precipitate the proteins and to decompose the residual bicarbonate to carbon dioxide. This carbon dioxide was examined in the mass spectrometer and was found to contain less C^{13} than the material at the start; this meant that it had been diluted by the carbon dioxide from the respiring liver cells. The urea formed in the solution was isolated chemically and converted into carbon dioxide which, on mass spectrometric analysis, was found to contain about half as much C^{13} as the carbon dioxide from the solution. Thus, said the authors, half the carbon of the urea comes from the bicarbonate put into the solution. They felt justified in assuming that the other half comes from carbon dioxide produced in tissue respiration. In any case they considered it proved that carbon dioxide is the chief source of urea carbon. No labelled carbon was found in the proteins of the liver tissue.

Tracer Experiments on Ductless Glands

The Thyroid Gland.—Tracer chemistry has been applied with some success to the functions and disfunctions of ductless glands. A good example is provided by the thyroid, which is a gland in the neck lying very close to the surface; it consists of two lobes lying on either side of the trachea joined together by the *isthmus* which crosses in front of the trachea just below the Adam's apple. The thyroid secretes a substance called *thyroxine* which, chemically, is an amino acid containing four iodine atoms in the molecule. The secretion has a profound effect on the metabolic rate of the individual.

The absorption of iodine by thyroid tissue can be studied with radio-iodine. Ordinary inactive iodine consists of the single isotope I^{127} but five radio-active isotopes are known of which the three most important are:

I^{131} : half-life 8 days,
I^{130} : half-life 12·6 hours, and
I^{128} : half-life 25 minutes.

Hertz, Roberts and Evans in 1938 used the last-mentioned isotope, '25-minute iodine', to study absorption and distribution in the rabbit. The isotope is prepared by the irradiation of inactive iodine with slow neutrons; the addition of a neutron to the nucleus of stable iodine (I^{127}) yields I^{128} which is unstable and decays with the emission of β and γ rays. This isotope was injected into rabbits and the radioactivity of various organs studied. Apart from the blood (into which it was injected) the only

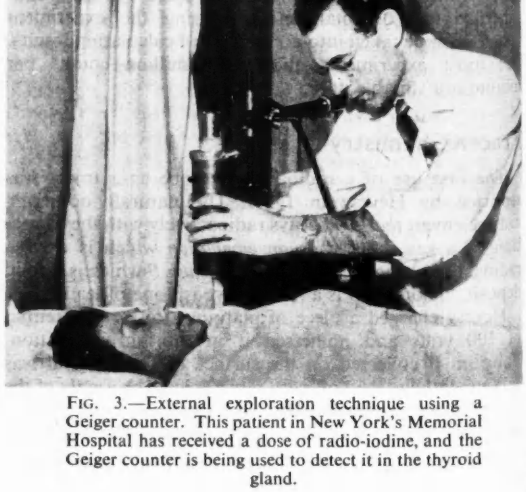


FIG. 3.—External exploration technique using a Geiger counter. This patient in New York's Memorial Hospital has received a dose of radio-iodine, and the Geiger counter is being used to detect it in the thyroid gland.

other sources of radioactivity found were the urine (which meant some iodine was being excreted) and the thyroid gland.

In iodine-deficient rabbits the activity of the thyroid increased rapidly after the first dose but then increased more slowly. This furnished a useful piece of information. When iodine-deficient patients are being treated by administering ordinary iodine, the question arises: Is it better to give one big dose or a number of small doses? The experiments with radio-iodine on rabbits show that maximum absorption occurs with the first dose and that therefore in ordinary therapy one dose is sufficient, and very little advantage is gained by administering many small doses.

Hamilton and Soley* used 8-day iodine to investigate iodine uptake in the three illnesses due to thyroid misbehaviour. The iodine isotope is prepared by the bombardment of tellurium metal with deuterons when a number of complex nuclear changes take place resulting in the iodine isotope. After bombardment the tellurium is mixed with potassium iodide as a carrier for the same reason as carrier lead was used in Hevesy's experiments with thorium B: the amount of radio-iodine is too small to manipulate so it is mixed with inactive iodine and the whole worked up together.

There are three pathological conditions of the thyroid: *hyperthroidism* or Graves Disease, *hypothroidism* or myxoedema, and non-toxic goitre. In Graves Disease too much thyroxine is produced by the gland and the metabolic rate is therefore too high. There is rapid pulse, general nervousness, excessive sweating, bodily wasting, protrusion of the eyes and often heart damage. In myxoedema the conditions are reversed. Too little thyroxine is produced: the patient becomes mentally dull, there is loss of memory, speech and movement is slow, the eyes become baggy and the skin dry and thickened. The third condition is non-toxic goitre which is due simply to insufficient iodine in the diet; here there is considerable enlargement of the gland.

Hamilton and Soley administered radio-iodine by feeding to patients of all three classes and also to a normal individual as a control. As the thyroid is so near the surface the γ-radiation could be measured by the external exploration technique—that is to say the Geiger counter is approached to the outside of the neck and the radioactivity measured as shown in the picture (Fig. 3). The curves obtained by plotting the uptake of radio-iodine against time on a graph are shown in the figure (Fig. 2).

These curves show that in non-toxic goitre the gland absorbs iodine in the same way as does the normal gland but to a greater degree—there is, in fact, too much gland. In myxoedema the gland is barely functioning at all as indicated by the very small iodine uptake; in Graves Disease the gland absorbs iodine very quickly but quickly loses a good deal of it, showing that retention is deficient.

Insulin.—Insulin is the secretion of the pancreas which regulates the level of sugar in the blood. This is normally about 100 milligrams per 100 cc. but in failure of insulin secretion the concentration rises to six or seven times that figure and the symptoms of diabetes appear. Insulin is protein in nature and has not been synthesised, hence it is not possible to prepare insulin itself with one of its atoms tagged. There is, however, a derivative of insulin (the *p*-iodo diazonium compound) which can be prepared containing radio-iodine. This compound still shows the physiological properties of insulin.

In experiments carried out by Reiner, Keston and Green (1942) ten rabbits were injected with the preparation and then killed at intervals, the blood sugar being determined just prior to killing. The skin and the abdominal wall at the site of injection was cut out, oxidised chemically and assayed for radioactivity. As the insulin compound was absorbed by the animal the radioactivity at the site of injection obviously diminished: the rate of diminution of radioactivity being equivalent to the rate of absorption of the compound. As the blood sugar was also known for each animal prior to killing, it was possible to demonstrate that the minimum blood sugar coincided with the maximum rate of absorption. The results obtained by these authors are shown in Fig. 4.

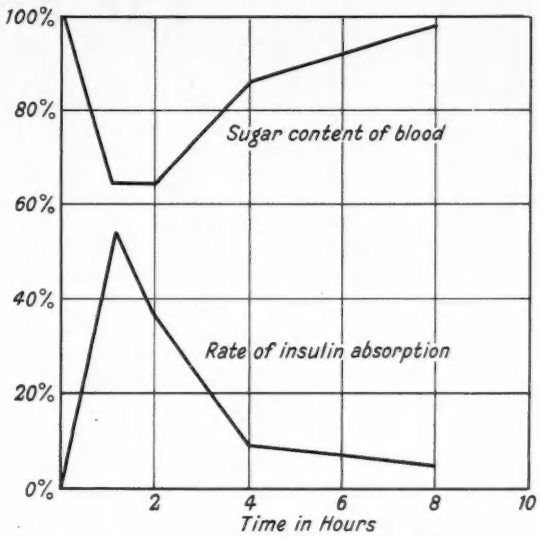


FIG. 4.—Correlation between rate of tagged insulin absorption and relative blood sugar.

The upper curve shows the variation of blood sugar over a period of eight hours, the normal value before treatment being taken as 100%.

The lower curve shows the variation in the *rate* of tagged insulin absorption per cent per hour over the same period—*not* the total insulin absorbed at the time of each reading but the *rate* in per cent per hour at the time of the reading.

Note that maximum rate of absorption of tagged insulin coincides neatly with minimum blood sugar.

* Quoted by Pollard and Davidson.

Far and Near

Isaac Newton Observatory

SOME details of proposed organisation of the Isaac Newton Observatory at Herstmonceux are given in the 1947 report of the Royal Society's Council. This observatory is to be equipped with an 100-inch reflecting telescope (see 'The Isaac Newton Telescope', by Professor H. H. Plaskett, DISCOVERY, October 1945, p. 311). The administration of the observatory is to be vested in the Astronomer Royal, who will be chairman of a special board of management including the directors of the Royal Observatory, Edinburgh, Cambridge Observatory and Oxford University Observatory, four nominees of the Royal Society and four nominees of the Royal Astronomical Society. The estimated maintenance costs of about £4000 a year will be met from the Navy votes, and the capital costs, understood to be in the region of £250,000, will also be defrayed by the Government.

New Electrical Laboratories at Stafford

THE new research laboratories, known as the Nelson Laboratories, of the English Electric Company were opened by the President of the Board of Trade on November 5. These laboratories consist of two groups, the first adjoining the company's works at Stafford and the other at Blackheath Lane near Stafford. The work of the first group is divided into ten sections: high power, high voltage, chemistry, insulation, general physics, vacuum physics, electrical, radiological electronics and metallurgical.

In the high-power laboratory there are two installations which can produce instantaneous short circuits (of 2½ million kilo-volt ampères) as severe as any that are likely to occur in the largest electrical networks in service in the world. The equipment of the high voltage laboratory includes a generator producing 3·2 million volts which will be used to study the effect of lightning on transformers, circuit breakers, etc.

In the Blackheath Lane Laboratories two electrostatic machines are being constructed of the Van de Graaf type and of 2 and 5 million volts respectively. The first is to be used for accelerating electrons, the other for accelerating electrons and protons. Several synchrotrons are also being developed: one type will yield 30 million electron-volt particles; the other 140 million electron-volt particles.

Gas-Turbine for Trafford Power Station

THE Stretford and District Electricity Board has been directed by the Central Electricity Board to install a 15,000 kW. generating plant driven by a gas-turbine at the Trafford Power Station. The new plant will be the first of its kind in the country, and is to be manufactured by Metropolitan-Vickers Electrical Co. Ltd. It will operate on the open cycle principle, burning fuel oil. It is anticipated that the thermal efficiency of the new plant at full load will at least be equal to that of the most efficient steam station.

Atomic Energy Committee Disbanded

IN 1945 the British Government appointed an Advisory Committee on Atomic Energy, under the chairmanship of Sir John Anderson. Five of its nine members were scientists, namely Sir Edward Appleton, Sir Henry Dale, Professor P.M.S. Blackett, Sir James Chadwick and Sir George Thomson. This committee has now been dissolved. Announcing this step the Government state that advice on the day-to-day operation of the programme of atomic energy development is obtained through the machinery of the Ministry of Supply, and on the broader scientific aspects of atomic energy development the Government can appropriately look for advice to the Advisory Council on Scientific Policy and the Defence Research Policy Committee, both under the chairmanship of Sir Henry Tizard. With this in view the appointment of an additional physicist to the Advisory Council on Scientific Policy is under consideration.

Prof. A. N. Whitehead (1861-1947)

PROF. ALFRED NORTH WHITEHEAD, O.M., who combined the study of science and philosophy in a way that is becoming more and more rare as the specialisation of science grows, died on December 30 at the age of 86 at Cambridge, Massachusetts.

Born at Ramsgate on February 15, 1861, he went to Sherborne School. After graduation in mathematics, he was elected a Fellow of Trinity College, Cambridge. He lectured on mathematics at Cambridge, and afterwards at University College, London, which he left to become Professor of Applied Mathematics at the Imperial College of Science where he remained until 1924. For the rest of his life he was Professor at Harvard University.

PROF. A. N. WHITEHEAD (1861–1947).

To the majority of our readers, Whitehead is best known through his books, *Process and Reality*, *Science and the Modern World*, and *Adventures of Ideas*. An earlier work with a great effect upon philosophy was *Principia Mathematica*, which he wrote with Bertrand Russell and which has been well described as marking "the culmination of the effort to treat mathematics as a department of logic".

Pulkovo Observatory Resumes Work

THE Pulkovo Observatory of the U.S.S.R. Academy of Sciences has resumed its work which was interrupted by the war. The re-assembling of a unique horizontal solar telescope, destroyed by a German shell during the blockade, is now under way. The observatory has designed a new instrument for the detailed study of the structure of the solar spectrum.

A Petroleum Research Centre has been established under the U.S.S.R. Academy of Sciences. The Centre will carry out investigations on the origin of oil deposits in the Soviet Union and study methods for improved exploitation of oil deposits. Academician Sergey Kametkin has been appointed director.

DSIR's Director of Radio Research

DR. R. L. SMITH-ROSE has been appointed to the new post of Director of Radio Research in the Department of Scientific and Industrial Research. At present this work is carried out in the Radio Division of the National Physical Laboratory and the Radio Research Station at Slough, other radio research being done for DSIR at the Telecommunications Research Establishment, Malvern. Eventually there is to be a new Radio Research Station.

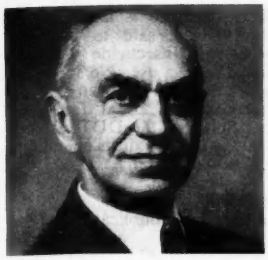
Dr. Smith-Rose, who is 53 years old, has been Superintendent of the Radio Division of the National Physical Laboratory since 1939. He has been responsible for conducting extensive investigations in radio direction finding, the electrical properties of soil and sea water and the propagation of radio waves over the ground and through the lower atmosphere.

Sanctuary for Gannets

GRASSHOLM, the island off the Pembrokeshire coast which is famous for its large population of gannets, has been bought by the Royal Society for the Protection of Birds. It has been computed that some six or seven thousand pairs of these birds nest on the island.

Who named the Telescope?

WHO coined the word 'telescope'? This question has long been the subject of controversy, and it is not surprising that the sorting out of the confused facts and opinions relating to it should prove a complicated piece of historical detective work. In *The Naming of the Telescope* by Dr. Edward Rosen (Henry Schuman, New York; Oxford University Press, Canada, 1947, pp. 110, $2.50) the author, who has done considerable research into the beginnings of modern astronomy gives the credit to the Greek, John Demisiani of Cephalonia. The term soon gained wider currency after its 'public unveiling' by Frederick Cesi at a banquet given in Galileo's honour on April 14, 1611, and was rapidly adopted instead of the more


PROF. F. C. BARTLETT.

DR. J. D. COCKROFT.

DR. H. R. RICARDO.

DR. R. V. SOUTHWELL.

ambiguous terms 'perspicillium' and 'instrumentum' which Galileo and Kepler used in their previous writings.

Science in the Honours List

THE importance of science and technology to the modern state was reflected in the New Year's Honours List. Many scientists received honours, including the following four fellows of the Royal Society who were knighted:

PROF. FREDERIC CHARLES BARTLETT, Professor of Experimental Psychology at Cambridge University. During the war he directed the Applied Psychology Unit of the Medical Research Council.

DR. JOHN DOUGLAS COCKROFT, first Director of the Ministry of Supply's Atomic Energy Research Establishment at Harwell since 1946. During the war he was superintendent of the Telecommunications Research Establishment. He was early associated with the 'Directorate of Tube Alloys', as the British atomic bomb project was called, and in 1944 he crossed the Atlantic to take charge of the atomic project in Canada, including development of slow-neutron piles at the Chalk River installation.

DR. HARRY RALPH RICARDO, famous for his researches on the internal combustion engine, which have had far-reaching influence upon the design of slide-valve engines, sleeve-valve aero-engines and high-speed Diesels.

DR. RICHARD VYNNE SOUTHWELL, Rector of the Imperial College of Science and Technology. Professor of Engineering Science at Oxford University, 1929-42. His development of relaxation methods for the solution of engineering problems is well known.

Night Sky in March

The Moon.—New Moon occurs on March 10d 21h 15m, U.T., and full moon on March 25d 03h 10m. The following conjunctions with the moon take place;

March					
3d 21h	Jupiter in conjunction with the moon,		Jupiter	4°	N.
8d 10h	Mercury	,,	Mercury	6	N.
14d 15h	Venus	,,	Venus	2	N.
21d 20h	Saturn	,,	Saturn	4	S.
22d 00h	Mars	,,	Mars	2	S.
31d 09h	Jupiter	,,	Jupiter	4	N.

The Planets.—Mercury is a morning star throughout the month. It rises about three-quarters of an hour before the sun at the beginning and middle of the month, and 20 minutes before the sun at the end of the month. Venus is an evening star, setting at 21h 30m, 22h 10m and 22h 54m, at the beginning, middle and end of the month, respectively. Mars is visible throughout most of the night, setting at 6h 45m and 4h 25m at the beginning and end of the month, respectively. Notice the close approach of the planet to the moon on March 22.

Jupiter rises at 3h 15m, 2h 25m, and 1h 30m, at the beginning, middle and end of the month, respectively. The close approach of Jupiter to the moon on March 31 should be noticed. Saturn rises shortly before Mars, to which it lies a little west.

A Cold Virus Isolated

THE isolation of a virus that causes one type of cold was reported in *Science* in December by Dr. Norman H. Topping and Dr. Leon T. Atlas of the U.S. Public Health Service. It has been named V14A. Under the electron microscope, the cold-causing agent appeared to be "characteristic particles . . . of the same general size as viruses of the influenza type, but . . . readily distinguishable from them".

Radio Echoes from Moon

AT the beginning of 1946 scientists working with U.S. Army radar equipment at the Evans Signal Laboratory made radio contact with the moon (DISCOVERY, Vol. 7, p. 62). According to the official Australian News Bureau, Australian scientists have repeated the feat using frequencies lower than those used in the American experiments. They were allowed to 'borrow' the 50 kW. short-wave broadcasting station of Radio Australia at Shepparton, Victoria, and this was linked to the CSIR receiving station at Hornsby, N.S. Wales, about 350 miles away, by landline. Rotating cams were used at Hornsby to produce the keying signals in predetermined groups. The most frequently used were a group of three pulses, each one-tenth second long, or alternatively a single pulse 2·2 seconds long.

The Shepparton transmitter operated on its allotted frequencies of 17·84 and 21·54 mc/s and broadside aerial arrays regularly used for its transmissions to Canada and the U.S.A. A rhombic aerial system was erected at Hornsby, where the echoes were received and recorded.

Echoes were first received on November 7, 1947, at 0355 (Eastern Australian Standard Time) when the moon got sufficiently high in the sky for the 17·84 mc/s radiation to penetrate the F2 region of the ionosphere, and the performance was repeated successfully on the following three nights.

The echoes, returning after 2·66 seconds, had a frequency about 50 mc/s higher than the transmitted signals—the earth's rotational velocity caused the point of observation to approach the moon, giving rise to a Doppler shift.

Lack of Graduate Science Teachers

THE teaching of Science among other subjects is threatened because of the shortage of graduate teachers in schools. This point emerged from a discussion at the annual meeting of the Incorporated Association of Headmasters, where it was stated that whereas in 1938 the percentage of teachers who were graduates was 16½%, it was now only 5%. Dr. W. T. S. Stallybrass, Vice-Chancellor of Oxford University, said that the competition was not between the schools and professions, but between schools and industry and the Civil Service.

Chemical Warfare Plant made DDT

THE Sutton Oak Factory of Britain's Chemical Defence Research Establishment did not devote all its efforts during the recent war to the production of poison gases. Among other materials which it turned out in large quantities was DDT. A pilot plant for this insecticide was operating in 1943, and by the summer of 1944 the factory was despatching 10 tons a week. In all over 600 tons were produced.

For the Medical Research Council, methionine was prepared in quantity at Sutton Oak. Before the war this substance, which was needed for curing the jaundice that treatment with salvarsan can cause, was available only in very small quantities and was expensive. The output from Sutton Oak brought about a reduction in the catalogue price of methionine from 8*s.* 6*d.* a gram to 10½*d.*, according to an article on the factory's contribution to the war effort in the December issue of *State Service*. A technical description of methionine production at Sutton Oak appeared in the *Journal of the Society of Chemical Industry* recently (1947, Vol. 66, pp. 365–373).

Exhibitions for Dominion Students

IN VIEW of the difficulties which prevent students residing in the Dominions (other than Eire) and Colonies from competing in the annual open examination for scholarships and exhibitions, Trinity College, Cambridge, is prepared to consider applications made by dominion and

colonial universities on behalf of such students under special conditions, particulars of which can be obtained from the senior tutor of Trinity College. Selected candidates may study for an Honours B.A. or for a higher degree (Ph.D., M.Litt. or M.Sc.). Applications in connexion with these dominion and colonial exhibitions have to reach the senior tutor by May 1.

A Research Studentship is offered by the college every year, and an election will take place in July 1948. Candidates must be graduates of some university other than Cambridge, or who can show evidence of exceptional qualification for research. The age limit is 26 years on May 1 (the date by which all applications must be received); ex-servicemen can deduct their length of war service from their actual age. Applications have to be sent through the head of the candidate's university.

New Insecticides

Two promising new organic insecticides are being tested in the United States. One of them, *tetraethyl pyrophosphate*, gives 90% and 95% kills of aphids and mites at dilutions between 1 : 10,000 and 1 : 20,000. It is likely, however, to be highly toxic to man and warm-blooded animals.

The other substance is *diethyl nitrophenyl thiophosphate*, said to be more toxic as a contact insecticide than any other chemical now in use. No species of insect or mite yet tested has been resistant at the concentrations usual for other insecticides. Some of the DDT-resistant pests are 100% killed by dusts containing 0·2% of this new material.

DSIR Publications

A LIST of all available publications of the Department of Scientific and Industrial Research is now available free of charge from H.M. Stationery Office, Section S.P., 429 Oxford Street, London, W.C.1.

JUNIOR SCIENCE

How the Eye Works—I

LAST month I wrote about feeling pressure (or touch), heat and cold, and pain, with the skin. There are several organs of the body that are specially constructed so that they react to what is going on outside the body. The skin, as we have seen, is one. Another is the eye, which responds to light.

What does this mean? First, we cannot see anything in complete darkness. (What's more, nor can any other animals: when you hear of cats or owls 'seeing in the dark', that really means that they can see in a very dim light.) If there is only a very faint light indeed—for instance, that entering a window on a dark night, all we can see is a patch of light: we can distinguish, in fact, different *degrees of brightness*; as it gets lighter in the morning we begin to be able to distinguish the *shapes* of things; later still we can see their *colours*.

How does the eye do all this? One way of understanding how it works is to compare it with a camera. A camera has a sensitive film or plate at the back and a lens in front. In the eye the sensitive part is called the *retina*. Of course, it is far better than any film, because it can deal with a constantly changing scene, and it renews itself all the time.

The retina is made up of a lot of very small light-detectors. In the skin (as we saw last month) you have cold and other detectors scattered about. In the eye the light detectors are concentrated in one place. Here is an experiment that illustrates the way the retina is arranged. Make two small ink spots very close together on a piece of paper. Then close your left eye and look at the spots with your right eye. The paper should be about ten inches away. Then turn your eye very slowly to the left of the spots, so that you gradually look farther and farther away from them. You will still be able to see the spots, even though you are not looking directly at them. At first you will see them as two spots. Then they will become less clear and will look like one blob. Then, quite suddenly, as you go on turning your eye away, they will disappear. But they will reappear as you turn your eye still farther.

Now for the explanation. The first thing obviously is that different parts of the retina differ in the accuracy of the picture they give you. When you look straight at something you see it clearly. The central, sensitive part of the retina can therefore be compared with the most sensitive kind of film—the fine grain type used in a miniature camera. On the other hand the picture you get with the outer parts of the retina is indistinct, like a bad newspaper reproduction of a photograph.

But none of this explains the disappearance of the ink spots. Why have we this *blind spot* on the retina? The blind spot is the area where the eye *nerve* runs back from the retina towards the brain. Each light-detector in the retina is connected to a single, very fine nerve fibre. These fibres run over the inner surface of the eye, and come together to form the eye nerve. You might compare them to a lot of single telephone wires from different places that come together to make a bundle leading to the exchange.

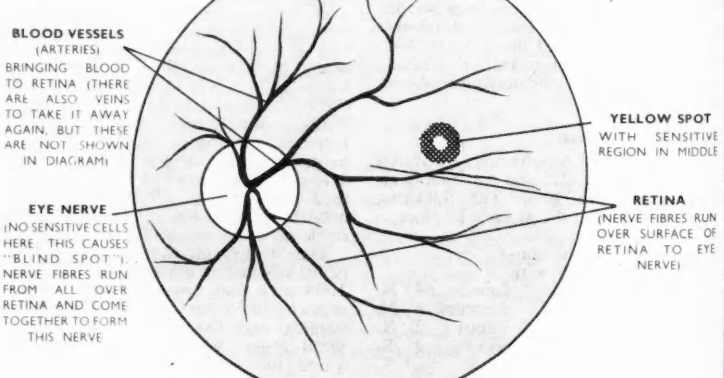
The fibres are on the inner surface of the retina, and so the light has to pass through them to reach the light-detectors. That is all right, because the fibres are transparent. But where they meet to form the eye nerve there are no detectors at all; and this point with no detectors is the blind spot.

The blind spot does not worry you in the ordinary way. If you are using both eyes one eye cancels out the effect of the blind spot of the other. But even if you are using only one eye you automatically and unconsciously allow for the area you cannot see.

The central part of the retina is not only the most sensitive part; it is also the part with which you distinguish the different colours. You cannot see colours out of the corner of your eye. (You might try to work out a way of testing that.) The colours you see are due to the different wavelengths of the light rays that enter the eye. To distinguish different colours the eye must have several different kinds of detector, each reacting to different colours. A good comparison is with radio sets tuned for receiving wireless waves of different wavelengths.

Next month I shall describe how other parts of the eye work.

ANTHONY BARNETT.


BLOOD VESSELS (ARTERIES) BRINGING BLOOD TO RETINA (THERE ARE ALSO VEINS TO TAKE IT AWAY AGAIN, BUT THESE ARE NOT SHOWN IN DIAGRAM)
EYE NERVE (NO SENSITIVE CELLS HERE. THIS CAUSES "BLIND SPOT"). NERVE FIBRES RUN FROM ALL OVER RETINA AND COME TOGETHER TO FORM THIS NERVE
YELLOW SPOT WITH SENSITIVE REGION IN MIDDLE
RETINA (NERVE FIBRES RUN OVER SURFACE OF RETINA TO EYE NERVE)

If you imagine you are looking at the inside of the eyeball through the pupil, this is part of what you would see.

The Bookshelf

Natural History in the Highlands and Islands. By F. Fraser Darling. (Collins, London, 1947; pp. 303, 16*s.*)

THIS volume is No. 6 in the New Naturalist series and is a welcome addition. The author has avoided the mistake of trying to say the last word on any one topic of the many he discusses. Throughout the whole book his approach is a social one by which he tries to assess all the factors influencing the environment, and he shows how changes in husbandry and other factors have caused wide changes in the fauna and flora. He makes many suggestions for rehabilitation of the area and preservation of species in danger of extinction.

The highlights of the book are those chapters dealing with subjects in which the author has done research. The sections on red deer, seals and sub-oceanic islands are most engrossing. While not reaching the completeness of these chapters the rest of the book is accurate and stimulating. The writer detected only two very minor inaccuracies. Firstly he disagrees that the source of the River Dee is at the Pools of Dee (p. 27) but suggests it is at the Wells of Dee on Braeriach, 1300 feet higher. Secondly he has found the pale butterwort (*P. lusitanica*) at Achininver, Achiltibuie, which is farther north than suggested by the author (p. 36). Much work is still to be done in this area and one of the greatest values of the book is the posing of some of the problems worthy of attention by amateur and professional biologists.

The book is well illustrated by both black and white and colour photographs. In particular the bird photographs reach a high standard. In places, the colour reproduction does not seem quite true.

The author concludes with a strong appeal for conservation and control by enlightened methods in the area. Here is a book written by one who has lived with his subject and is in sympathy with it, and it should help immeasurably to achieve the aim of the series "to interest the general reader in the wild life of Britain by recapturing their inquiring spirit of the old naturalists". J. F.

The Electron Microscope. By V. E. Cosslett. (Sigma Books, London, 1947; pp. 128, 7*s.* 6*d.*)

THIS is an excellent addition to the series of Sigma 'Introductions to Science', and contains one of the best general accounts of the techniques used in electron microscopy yet published. The basic principles governing the design of the various types of electron microscope and their respective limitations are set out clearly, without the use of mathematics. The commercial instruments which have been developed in this country and abroad are compared and contrasted, and some of the less orthodox experimental models are described.

Some of the achievements of the present instruments in the fields of biology, medicine, metallurgy and polymer chemistry are discussed, and the extraordinary interest of the new range of dimensions which have now become visible in the study of the origins of life is demonstrated.

An interesting final chapter on future possibilities shows the lines along which improvements are to be expected, some of which have been realised since the book was written. These improvements are not confined to the achievement of still greater resolving powers and magnifications, but include improvements in the techniques of specimen preparations which will greatly extend the applications of the instrument. C. G. A. H.

Drought, its causes and effects. By I. R. Tannehill. (Oxford University Press, London, 1947; pp. 264 + 118 illustrations, 15*s.*)

THOSE living in the maritime climate of the British Isles have little experience of the hardships and dangers of drought. 1947 will long be remembered as a year of abnormally low rainfall, but the memories will mainly be of gloriously sunny weather. In some areas the drying up of reservoirs caused minor hardships, and the poor growth of crops will be reflected in our rations, especially milk.

In other parts of the world, however, a deficiency of 20% of the normal rainfall may have the most serious consequences, causing crop failure, perhaps famine, and greatly increased soil erosion. The United States, particularly the great plains, are one of these regions. Mr. Tannehill has attempted to analyse critically the meteorological factors which may have been responsible for drought there. Whilst frankly admitting that he has not completely solved the problem, he lays great stress on the relative temperature of the Pacific Ocean combined with solar variation. His claim that the underlying causes of climatic change may be obscured by the current practice of thinking either in terms of synoptic charts or in figures based on normals and not on spells is worth serious consideration by climatologists.

The Oxford Press are to be congratulated at producing, at such a low price, a book so informative, so well illustrated and with 13 pages of climatic data and an 8-page bibliography for further reading. J. F. KIRKALDY.

The Growth of Physical Science. By Sir James Jeans. (Cambridge University Press, 1947; pp. 364, 13 plates, line drawings, 12*s.* 6*d.*)

THIS is a very simply told tale of the development of mathematics, astronomy, physics and chemistry from the Egyptian Mesopotamian civilisations to the present day. It aims only to be a work of popularisation, and for that purpose the selection of themes to be treated has been extremely well done. The interconnexions of various events in the history of science have been well treated, and the trap of presenting the work of geniuses as if it were done in isolation has usually been avoided—for example, pages 182–3 make it quite clear how much the idea of the inverse square law of gravitation was in the air before Newton brought his superb technique to bear on it. There are even occasional hints at the relation of science to its social background, though these are not always sound—it is surely an unwarrantable exaggeration to say that in their early days the Royal Society and the French Academy of Science "were mainly concerned with the development of utilitarian science, the study of industrial arts, and the improvement of technical processes". For a book by Sir James Jeans it is hardly necessary to add that the exposition is straightforward and lucid.

I should recommend the book wholeheartedly as an introduction to the history of physical science for the layman, if it were not for one major fault—it is full of simple factual errors. On the back of the title page the publishers announce that the proofs had been revised by the author shortly before his death. If that is the case one can only assume that failing health prevented him from doing the revision thoroughly. As it is, the frequency of these errors makes it difficult to recommend the book to the layman. S. L.

The Mind of the Bees. By Julien Françon. Translated by H. Eltringham. (Methuen, London, 2nd Edn., 1947; pp. 146, 7*s.* 6*d.*).

To my mind this book is one of the most stimulating and at the same time one of the most irritating that I have ever read.

Unfortunately perhaps, as the author himself states in the introduction to his book, Françon devoted little time to a study of the work of other observers on bee behaviour and psychology. This allowed him to approach the subject with an open mind but, although his experiments appear to follow one another in a perfectly logical sequence, I, amongst other students of bee behaviour, feel unable to accept all the conclusions drawn until such time as these most interesting experiments have been repeated on a much larger scale. It is, on reading this book, difficult for a worker who knows the magnificently detailed, controlled, and many times repeated experiments on bee behaviour carried out by von Frisch, Kalmus, Park, and other workers, to accept without reservation many of the conclusions reached by Françon. If only Françon had carried out his work on a larger scale and with more frequent repetition of his experiments one would feel justified in proclaiming that his work was of the same order of importance as that of, let us say, von Frisch. I feel that some of his conclusions must, until supported by further evidence, be accepted with considerable reservation.

It is the presence of these very reservations in one's mind that make this book so stimulating and so irritating. To give but two examples. If Françon had known the literature it seems unlikely that he would have used red and white dahlias in an experiment in the mistaken idea the honeybee perceive red as a distinct colour.

Actually, of course, red appears as some shade of grey to the honeybee. This fact, however, does not, as pointed out by Dr. Eltringham in his preface, in the least invalidate the author's conclusion that a worker honeybee can indeed communicate to her sisters the presence of syrup in association with a flower of a definite colour (or shade of grey) distinct from other flowers of the same shape, and with a similar perfume (?) growing in the same bed. If this conclusion is a correct one it is indeed a very important discovery and one longs to see it repeated under conditions that are better controlled. Can we be certain that there was to the bees no distinctive perfume which served to distinguish the red from the white dahlias? We already know that bees can and do recognise flowers by their perfume and can by means of the perfume in the nectar collected transmit to their sisters information as to its source. Was then this possible source of error excluded from this experiment?

In a chapter in which he describes an experiment on home-finding by the honeybee Françon states that a marked bee which was moved in a closed cardboard box to a position over 1000 yards from her hive on being released took flight at once and made in a straight line directly for her apiary. This experiment he repeated 'several times', always with the same result. This observation clearly conflicts with the general experience of bee research workers who have noted that on liberation from confinement in a container a bee always flies around in concentric circles of ever increasing size until she locates some landmark known to her.

Although the first English edition of Françon's book appeared nearly eight years ago no successful attempts to obtain data in support of his main conclusions have so far been reported. Until these conclusions have been confirmed by other observers it would seem to be a pity that Françon's work should receive more attention from beekeepers and other interested people than the important conclusions concerning the mind of the bee reached by von Frisch as a result of his exemplary work. C. G. BUTLER.

Apes, Giants and Man. By Franz Weidenreich. (University of Chicago Press, 1946; Cambridge University Press; pp. 122, 14*s*.)

PROFESSOR Weidenreich of the American Museum of Natural History is well known for his contributions to the study of Pekin Man. His little book presents five lectures delivered at the University of California, on the physical evolution of man. Each lecture dealt with one self-contained topic, namely: Man and his simian ancestry, the development of the specifically human form, giants as earliest ancestors, principles of classification and origin of human races, and form and qualities of the human brain and skull in the light of evolution.

The outstanding chapter is that on human races. In it Weidenreich shows the inefficiency of the various systems of classification and the factors which make it so difficult to sort out humanity into watertight compartments. The interference of 'constitutional types' with racial definitions is demonstrated, and how the distribution of blood-groups among the races does not agree with the system based on skin and hair. He then proceeds to explain his hypothesis of parallel evolution, according to which the modern Australians are descendants of Java Man (*Pithecanthropus*), the modern Mongoloids of Pekin Man, and so forth. With European Man the author gets into difficulties, as no fossils suitable for his hypothesis are known from this continent. The chapter dealing with the human brain undertakes to show how unreliable the interpretation of our various indices is. That the volume, or weight, of the brain means little is obvious, but even its size relative to body size fares badly. The greatest expansion of the brain case was apparently attained in the Neanderthal stage of evolution, and in more recent times the changes appear to have been concerned with the form of the skull, possibly coupled even with a slight reduction in average size. A summary of racial theories based on the shape of the skull provides entertaining reading. Weidenreich concludes that the number of round-heads is steadily increasing, and that this is the natural trend of evolution, connected with the further adjustment of the head to erect posture.

The other three chapters deal with fossil evidence and contain a rather greater amount of speculation. Weidenreich points out that the large Mauer jaw, *Pithecanthropus robustus*, *Gigantopithecus* (teeth from China) and *Meganthropus* (a jaw fragment from Java) suggest that types of a size exceeding modern man are present in his ancestral line. But few readers will follow the author when he compares the expansion of the braincase of *Homo* with the expansion observed in dwarf races of dogs. As to the evolution of man in general, his main thesis is one of polyphyletic origin of the major modern races as I have indicated already. This idea is, to say the least, not easy to substantiate on the evidence available and, on the contrary, to defend it it is necessary to disregard certain finds and the chronological sequence of some of the fossils. Weidenreich feels strongly that all human fossils, from Pekin and Java Man onwards, represent taxonomically speaking one Linnaean species, but unfortunately he refuses to adapt the exceedingly muddled nomenclature of the anthropologists to the Rules of Zoological Nomenclature. Sooner or later this will have to be done. F. Z. E.

The Practical Radio Reference Book. Edited by R. C. Norris. (Odhams Press, London, 1947; pp. 288, illustrated, 8*s*. 6*d*.)

Radio: A Study of First Principles. By E. E. Burns, 3rd Edn. (Van Nostrand, New York; Macmillan, London, 1947; pp. 293, illustrated, 15*s*.)

THE first book contains an enormous quantity of practical information, covering units of electrical quantities, most of the circuits used in present-day broadcast receivers, extensive tables of valve data, wire tables, properties of dielectrics, colour codes, information on the propagation of radio waves, design of simple measuring equipment, etc. The section on units includes, incidentally, an excellent thumb-nail summary of the features of the M.K.S. system of units. The author has, however, fallen into one trap in the section on 'Frequency Changers': he regards the 'adding' of two frequencies in a non-linear device in order to produce a difference frequency as a 'heterodyne' method, but the multiplication of the two inputs in a two-control-grid valve as a 'modulation' and therefore not a heterodyne process. The truth is, of course, that the adding of two signals at the *input* of the non-linear device leads to an *output* including the product of the two input components, *i.e.* there is in this case also the multiplication which is essential to the production of a difference frequency. Perhaps wisely, no attempt has been made to cover television in this edition, but the book can be recommended to all concerned with the construction or repair of broadcast receivers.

In the preface to the third edition of his *Study of First Principles*, E. E. Burns declares his admirable intention of giving the beginner an understanding of the mode of operation of radio circuits and giving the more experienced worker an opportunity to consolidate his knowledge of fundamental theory. The experimental method of approach is good didactically, and should appeal to those whose introduction to radio was through war-time training courses. But unfortunately the execution is not so good, and mere good intentions pave the road. . . . It is, of course, desirable that a book of this type should be written by someone with strictly practical experience and outlook, but could not either the author or the publishers have persuaded a more high-brow engineer to check the text before it reached its third edition? On p. 5 we are told that "by inserting a variable condenser between the plate and grid circuits as shown in Figs. 9 and 10" a regenerative circuit is produced. Neither the circuit described in words nor the quite different circuit illustrated in Figs. 9 and 10 will function as a regenerative circuit. There is no mention of special frequency-changer valves, neither the American pentagrid nor the British hexode; and diode detection for the signal is omitted, though the author had perforce to introduce a diode detector into the paragraph on A.V.C. Although the third edition is stated in the preface to have been purged of obsolete matter, a large proportion of the circuit diagrams contain filament rheostats, and it is suggested that 175 kc/s is a normal intermediate frequency for a superheterodyne receiver. If this were the only type of book to be eliminated by dollar scarcity, there would be no cause for regret; but this volume is not typical of the technical works of its own and other reputable American publishers. D. A. B.

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